DOCUMENT RELEASE AND CHANGE FORM

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Assistant Secretary for Environmental Management
By Washington River Protection Solutions, LLC., PO Box 850, Richland, WA 99352
Contractor For U.S. Department of Energy, Office of River Protection, under Contract DE-AC27-08RV14800

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Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions

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Basis is required for Yes:

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7. **Description of Change and Justification** (Use Continuation pages as needed)

The DOE and its contractors, seek to analyze, in a hypothetical scenario, all possible dimethyl mercury (DMM) emission sources related to the tank farm operations, waste transfer, waste treatment, waste delivery to the Waste Treatment and Immobilization Plant (WTP), WTP operations, and secondary waste processing at the Hanford Site. This document serves as a second tier review and a HIA pursuant to the requirements of WAC 173-460-090, "Second Tier Review." The purpose of this report is to document the analysis of the potential human health related impacts of DMM emissions by evaluating the offsite ambient concentrations from the ventilation systems at the Hanford Site. This study is intended to determine if the DMM emissions from a hypothetical, conservative, and bounding emissions scenario that is representative of all sources pose an unacceptable risk to the public.

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Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions

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Abstract: The DOE and its contractors, seek to analyze, in a hypothetical scenario, all possible dimethyl mercury (DMM) emission sources related to the tank farm operations, waste transfer, waste treatment, waste delivery to the Waste Treatment and Immobilization Plant (WTP), WTP operations, and secondary waste processing at the Hanford Site. This document serves as a second tier review and a HIA pursuant to the requirements of WAC 173-460-090, "Second Tier Review." The purpose of this report is to document the analysis of the potential human health related impacts of DMM emissions by evaluating the offsite ambient concentrations from the ventilation systems at the Hanford Site. This study is intended to determine if the DMM emissions from a hypothetical, conservative, and bounding emissions scenario that is representative of all sources pose an unacceptable risk to the public.

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APPROVED
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Prepared by:
Washington River Protection Solutions, LLC

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EXECUTIVE SUMMARY

As required by *Washington Administrative Code* 173-460-080, "First Tier Review," projects with potential emissions of air toxics that exceed the *de minimis* levels outlined in *Washington Administrative Code* 173-460-150, "Table of Acceptable Source Impact Level, Small Quantity Emission Rate and De Minimis Emission Values," are required to submit a notice of construction application (referred to as "first tier review"). Pursuant to WAC 173-460-090, "Second Tier Review," if any toxic air pollutant is modeled to exceed the acceptable source impact levels, a second tier review, or health impact assessment, must be performed for that pollutant to demonstrate that the potential emissions do not present an unacceptable health risk to members of the public. In previous Hanford Site notice of construction applications, only dimethyl mercury emissions were consistently found to be above the acceptable source impact level.

The Hanford Site anticipates that submittal of numerous air toxic notice of construction applications will be needed to support the planned tank waste retrieval, transfer, and treatment processes within the Hanford tank farms and at the Waste Treatment and Immobilization Plant. For efficiency purposes, and to minimize the potential need to prepare multiple, similar health impact assessment documents in support of those future applications, this document is intended to present a health impact assessment that bounds those future potential emissions and satisfies second tier review requirements for future submitted notice of construction applications.

The hypothetical emissions scenario modeled and evaluated in this health impact assessment should easily bound all potential dimethyl mercury emission activities at the Hanford Site due to a number of conservative assumptions that overestimate emissions relative to what would reasonably be expected during operational activities. Multiple sources simultaneously operating year-round were selected to represent and bound the Tank Farm, Waste Treatment and Immobilization Plant, and secondary waste processing activities. Calculated dimethyl mercury emissions were increased by a factor of 100 for one tank in each tank farm, and then further increased by a factor of 100 during air dispersion and deposition modeling. Waste Treatment and Immobilization Plant air permit limits for elemental mercury were assumed to be all dimethyl mercury. Future planned facilities were assumed to emit at the same full rates.

In consultation with the Washington State Department of Ecology, the two human pathways identified that would result in the highest exposure to the public were: 1) inhalation and 2) ingestion of plants. Two exposure scenarios were used to calculate the potential hazard to the public: 1) 30-year mother-child living at the point of maximum 24-hour concentration and deposition and 2) 70-year resident living at the location of the nearest resident. Conservative assumptions were used to ensure that the calculated risk was an overestimation of the potential health impacts.

The results of the analysis presented in this document show that the total Hanford Site attributable non-cancer dimethyl mercury inhalation dose to the hypothetical maximally exposed person is 5.4E-03 $\mu g/m^3$ and the total Hanford Site attributable non-cancer dimethyl mercury ingestion dose to the hypothetical maximally exposed person is 6.3E-05 mg/kg body weight per day. At these exposure levels, the calculated hazard quotient is 6.7E-01, which is less than the allowable maximum value of 1.0.

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AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
ASIL	acceptable source impact level
BACT	best available control technology
CAS	Chemical Abstract Service
DOE	U.S. Department of Energy
DMM	dimethyl mercury
DST	double-shelled tank
Ecology	Washington State Department of Ecology
EMF	Effluent Management Facility
EPA	U.S. Environmental Protection Agency
ETF	Effluent Treatment Facility
HCB	hexachlorobenzene
HEPA	high efficiency particulate air
HIA	health impact assessment
HLW	high-level waste
HMS	Hanford Meteorological Station
HQ	hazard quotient
LAB	WTP Laboratory
LAW	low activity waste
LAWPS	Low Activity Waste Pretreatment System
MeHg	methyl mercury
NOC	notice of construction
NRC	National Research Council
PCB	polychlorinated biphenyls
PCE	perchloroethylene
PIC	Product of incomplete combustion
PT	Pretreatment Facility
REL	reference exposure limit
SQER	small quantity emission rate
SST	single-shelled tank
TAP	toxic air pollutant
tBACT	best available control technology for toxics
TCE	trichloroethylene
TWINS	Tank Waste Information Network System database
UTM	Universal Transverse Mercator
VC	vinyl chloride
WAC	*Washington Administrative Code*
WTP	Waste Treatment and Immobilization Plant

1.0 PROJECT SUMMARY

The U.S. Department of Energy (DOE), Office of River Protection and its contractors, Washington River Protection Solutions, LLC and Bechtel National, Inc. seek to analyze, in a hypothetical scenario, all possible dimethyl mercury (DMM) emission sources related to the tank farm operations, waste transfer, waste treatment, waste delivery to the Waste Treatment and Immobilization Plant (WTP), WTP operations, and secondary waste processing at the Hanford Site in Benton County, Washington.

As required by *Washington Administrative Code* (WAC) 173-460-080, "First Tier Review," projects with potential emissions of air toxics that exceed the *de minimis* levels outlined in *Washington Administrative Code* 173-460-150, "Table of Acceptable Source Impact Level, Small Quantity Emission Rate and De Minimis Emission Values," are required to submit a first tier review, or notice of construction (NOC) application. If any toxic air pollutant is modeled to exceed the acceptable source impact levels (ASIL), a second tier review is conducted (WAC 173-460-090). Historically, as found in RPP-ENV-48231, "Second Tier Review Petition for the Operation of the 241-SY, 241-AP, and 241-AY/AZ Tank Farm Ventilation System Upgrades," and after applicable abatement credits are applied (Section 5.2) the only toxic air pollutant consistently modeled to exceed the ASIL is DMM. The ASIL for DMM is very low and is not based on toxicity data, but is highly conservative based on a history of death caused by DMM. As a result of prior first tier reviews and as required by WAC 173-460-090, it is assumed that a second tier review, or health impact assessment (HIA), will be required for DMM in future NOC applications.

The goal of this document is to analyze all possible DMM emission sources related to the tank farm operations, waste transfer, waste treatment, waste feed, and secondary waste processing. The hypothetical emissions scenario used for this HIA bounds all potential activities at the Hanford Site. Numerous sources were included in the HIA to represent all of the tank farm, WTP, and secondary waste processing areas of the Hanford Site. Calculated DMM emissions were increased by a factor of 100 for one tank in each tank farm, and then further increased by a factor of 100 during air dispersion and deposition modeling. WTP permit limits for elemental mercury were assumed to be all DMM and modeled at their maximum allowable value. Planned, new facilities were assumed to have DMM emissions equivalent to 100% of permit limits for similar existing facilities. All sources were assumed to be simultaneously operating year-round. The actual expected emission rates are well below the hypothetical scenario emissions rates. The overly conservative emission rates were developed to bound all future activities at the Hanford Site, while keeping the scenario general enough that many activities could be assumed to be accounted for within the HIA. It is assumed that the scenario chosen is highly conservative and will cover most, if not all, future activities on the Hanford Site (e.g., one or more waste disturbing activities in a single tank farm, full operation of WTP while multiple waste disturbing activities take place in tank farms, multiple waste retrieval activities, etc.).

As detailed in Section 2.1, there are several potential emission sources based on varying current and potential activities at the Hanford Site. In order to encompass all these activities, the sources

chosen for the HIA are considered representative of all Hanford Site activities, and bound all current and future emissions of DMM and the other neurotoxins considered in this HIA.

This document serves as a second tier review and a HIA pursuant to the requirements of WAC 173-460-090, "Second Tier Review." In addition, as stated in 08-02-025, "Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources," this HIA will also assess all toxic air pollutants (TAP) which have similar exposure effects as DMM and exceed the small quantity emission rates (SQER). Due to the hypothetical and bonding nature of the modeled emission scenario, it is expected that this HIA will be used to satisfy second tier review requirements for future Hanford Site air toxic NOC applications.

1.1 REPORT PURPOSE

The purpose of this report is to document the analysis of the potential human health related impacts of DMM emissions by evaluating the offsite ambient concentrations from the ventilation systems that will support retrieval and treatment of the tank waste at the Hanford Site. This study is intended to determine if the DMM emissions from a hypothetical, conservative, and bounding emissions scenario that is representative of all sources pose an unacceptable risk to the public. This evaluation is not intended to address all human exposure to DMM or mercury in south central Washington.

1.2 METHODOLOGY

The following process was followed.

1. Estimate emissions from all potential sources involved in the processing of the tank waste on the Hanford Site (see Section 2.1 for source descriptions).

2. Identify sensitive populations.

3. Perform air modeling to predict ambient air concentrations from the ventilation systems.

4. Perform air modeling to predict deposition onto plants from the ventilation systems.

5. Calculate the total inhalation exposure from the operation of the ventilation systems.

6. Calculate the total ingestion exposure from deposition on plants from operation of the ventilation systems.

7. Calculate the total hazard from all Hanford Site DMM emission sources.

1.3 HANFORD TANK FARM HISTORY

The Hanford Site is located in south central Washington State in Benton County along the Columbia River and is approximately 581 square miles in size (Figure 1). The mission of the Hanford Site from 1943 to 1988 was defense-related nuclear research, development, and weapons production. Nine nuclear reactors along the Columbia River at the site were used to produce plutonium. The site also had facilities in the Central Plateau, called the 200 Areas, used to extract the dissolved and irradiated reactor fuel for weapons production. Underground single shell tanks (SST) were built to store the radiological and chemical waste from plutonium production beginning in 1943. One hundred forty-nine SSTs made of carbon steel surrounded by concrete were built ranging in volume from 55,000 gallons to approximately 1,000,000 gallons. Beginning in the 1960s after many of the SSTs began to leak, 28 double-shell tanks (DST) were built. The DSTs each hold at least 1,000,000 gallons (RPP-RPT-26040, "Pairwise Blending of High-Level Waste").

Since the last reactor was shut down in 1986, the site mission has been environmental remediation and clean up. Waste stored in the tanks consists of hazardous chemicals regulated under the *Resource Conservation and Recovery Act of 1976* and radioactive chemicals regulated under the *Atomic Energy Act of 1954*. In 1989, DOE, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology) agreed to the process and the required actions to comprehensively cleanup the Hanford Site (Ecology et al. 1989, "Hanford Site Federal Facility Agreement and Consent Order"). The current mission to clean up the 200 Areas includes moving the waste from the SSTs to the DSTs to prevent any further leakage, retrieving and treating waste from all 177 underground tanks and ancillary equipment, and disposing of the waste in compliance with applicable regulatory requirements.

2.0 FACILITY IDENTIFICATION AND LOCATION

The sources considered for this HIA are located at:

Hanford Site
U.S. Department of Energy, Office of River Protection
Richland, Washington 99354

Figure 1 provides a Hanford Site map. Locations of all modeled sources are contained within the Hanford Site boundary with the specific locations of those sources provided in Table 1. The region outside the yellow receptor boundary shown on Figure 1 represents the area where members of the public could be impacted from Hanford Site emissions. This area was evaluated for TAP emission impact to the public for purposes of this HIA. The yellow receptor boundary and the Hanford Site boundary are not the same. In order to evaluate all potential public locations, the Hanford Site boundary on the southeast side was shrunk so that the assessment could evaluate areas where members of the public can gain access (i.e., Laser Interferometer Gravitational-Wave Observatory, Energy Northwest, the 400 Area, the 300 Area, and the Hanford Dunes).

2.1 POINT SOURCES FOR TOXIC AIR POLLUTANT EMISSIONS

Several sources were considered for inclusion in the HIA, and were ultimately chosen to represent all of the tank farms, WTP, and secondary waste processing areas of the Hanford Site. The overly conservative emission rates were developed to bound all future activities at the Hanford Site, while keeping the scenario general enough that many activities not specifically described could be assumed to be accounted for within the HIA. It is assumed that the scenario chosen is highly conservative and will cover most, if not all, future activities on the Hanford Site (e.g., one or more waste disturbing activities in a single tank farm, full operation of the WTP while multiple waste disturbing activities take place in tank farms, multiple waste retrieval activities). The primary activities at the Hanford Site with the potential to emit DMM are tank farm operations, waste treatment, secondary waste processing, and waste processing supporting activities. These activities are detailed further in the following sections. The sources chosen to represent hypothetical emissions from these activities are representative of the potential emissions across the Hanford Site, and are not the only sources on the Hanford Site.

For specific stack parameters for each exhauster or emission point used in the hypothetical emissions scenario for this HIA, see Table 10.

Figure 1. Map of the Hanford Site

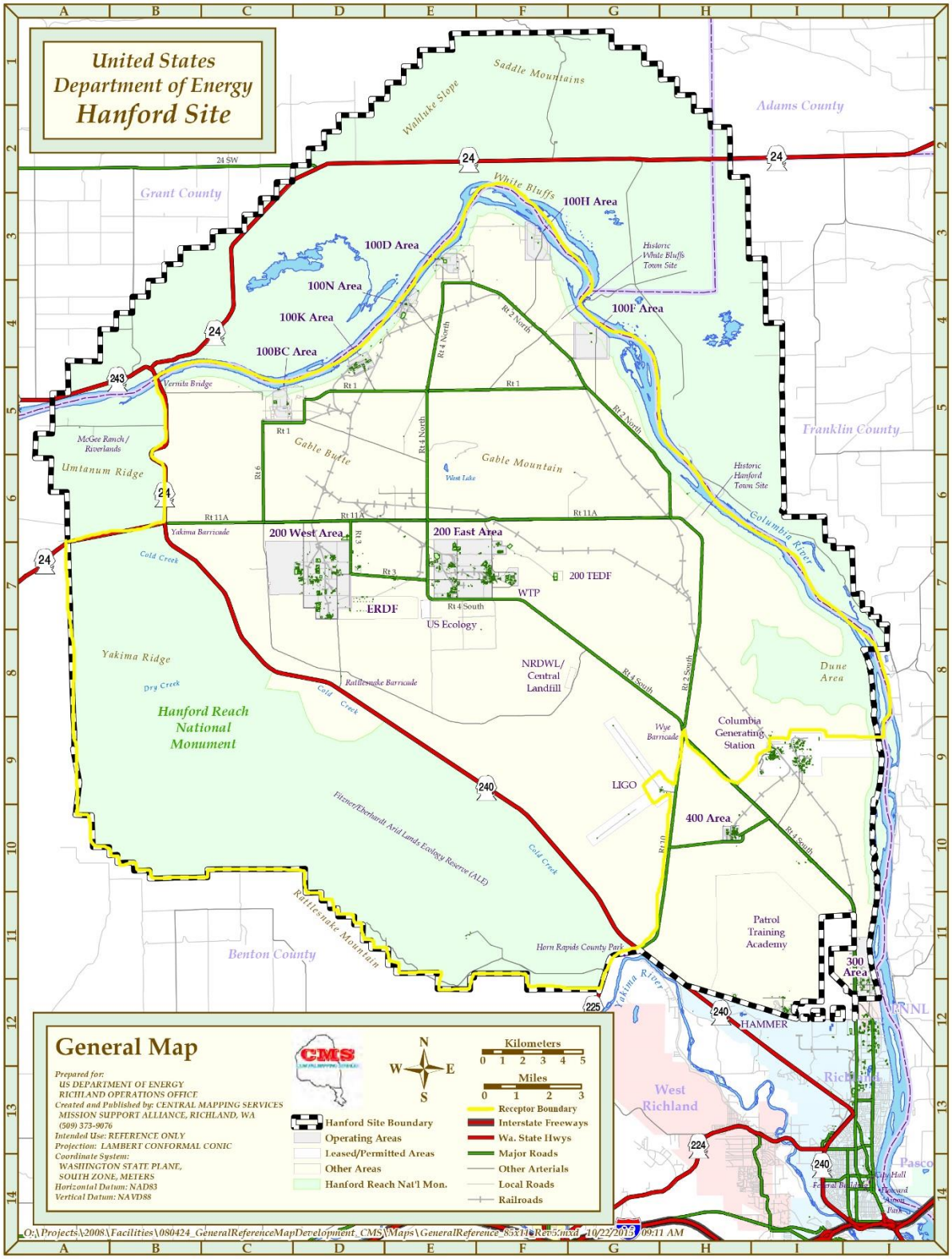


Table 1. Modeled Source Locations

Source	UTM		Location*
	East (m)	North (m)	
AN Tank Farm	307090	5158942	200 East Area
AP Tank Farm	307266	5158347	200 East Area
AW Tank Farm	307060	5158361	200 East Area
AY Tank Farm	307010	5158827	200 East Area
AX Tank Farm	306987	5158633	200 East Area
A Tank Farm	307063	5158760	200 East Area
S Tank Farm – Retrieval	298367	5157304	200 West Area
SY Tank Farm	298523	5157467	200 West Area
SX Tank Farm – Retrieval	298465	5157085	200 West Area
242-A Evaporator	307070	5158520	200 East Area
Effluent Treatment Facility	307520	5160066	200 East Area
LAWPS	307604	5158427	200 East Area
WTP-Pretreatment	307988	5158355	WTP
WTP-LAW	308047.7	5158256	WTP
WTP-HLW 1	307865	5158234	WTP
WTP-HLW 2	307865	5158234	WTP
WTP-LAB	308094.5	5158441	WTP
WTP-EMF	308157	5158507	WTP
Core Sampler	307037	5158594	200 East Area
Dryout Exhauster – A Farm	307050	5158827	200 East Area
Dryout Exhauster – B Farm	305560	5159912	200 East Area
Dryout Exhauster – C Farm	306846	5159170	200 East Area
Dryout Exhauster – BX Farm	305361	5159969	200 East Area

* As shown in Figure 1 in this document.

2.1.1 Tank Farms

The waste at the Hanford Site is held in tanks in the 200 West and 200 East Areas (Figure 1). Ten of the tank farms (A, AN, AP, AW, AX, AY, AZ, S, SX, and SY) were chosen to represent emissions from all of the tank farms on the Hanford Site. Some of the tank farms were chosen to ensure an even distribution of emission assessment across the 200 East and 200 West Areas. Other farms were strategically chosen based on the role they play in tank waste retrieval and

processing. The 241-AP Tank Farm will be the transfer point for low-activity waste (LAW) from the 200 East Area to the WTP. The 241-SY Tank Farm is the only DST farm in the 200 West Area and is the transfer point between the 200 West Area and the 200 East Area. The WTP is located in the 200 East Area, therefore 200 West Area waste must pass through the 241-SY Tank Farm to get to the WTP.

2.1.2 Waste Treatment

The current and planned tank waste treatment process at the Hanford Site includes the Low Activity Waste Pretreatment System (LAWPS) and the WTP. The LAWPS facility, which will pretreat LAW, is currently in the design phase and will be located near the 241-AP Tank Farm. The WTP is currently under construction in the 200 East Area of the Hanford Site. The WTP will treat and vitrify (immobilize in glass) the Hanford tank waste. The WTP consists of multiple facilities. All of the facilities within the WTP will generate liquid secondary waste streams which will be transferred to the Effluent Treatment Facility (ETF) for treatment and disposal. The Pretreatment Facility (PT) is the first facility in the WTP waste treatment process. PT receives the feed from the tank farms and divides the waste into LAW and high-level waste (HLW) streams for treatment and preparation for delivery to the applicable facilities. PT off-gas is treated and vented through a single stack. The LAW facility will accept a mostly liquid waste stream from PT, with a low radioactivity, and immobilize the waste stream in glass for disposal. All off-gas from LAW processes are treated and discharged through a single stack. The HLW facility will accept a concentrated waste stream with high radioactivity from PT for immobilization in glass. The HLW process includes two off-gas treatment processes and two stacks. The WTP Laboratory (LAB) will accept waste samples from PT, LAW, and HLW for process control analysis. The Effluent Management Facility (EMF) is in the design phase. It will support the balance of facilities processes at the WTP and manage LAW facility liquid effluents. The EMF will support the direct feed LAW campaign, which will process waste through the LAWPS facility directly to the LAW facility.

2.1.3 Secondary Waste Processing

The ETF and 242-A Evaporator will support the treatment facilities through secondary waste processing. The ETF will accept liquid secondary waste streams from the WTP tank waste treatment operations and other processing facilities on the Hanford Site. The secondary waste streams will be treated for disposal. The 242-A Evaporator is located in the 200 East Area. The unit treats DST waste by reducing waste volume through water extraction. The remaining waste then goes back to the DSTs. The condensate is transferred to ETF for treatment.

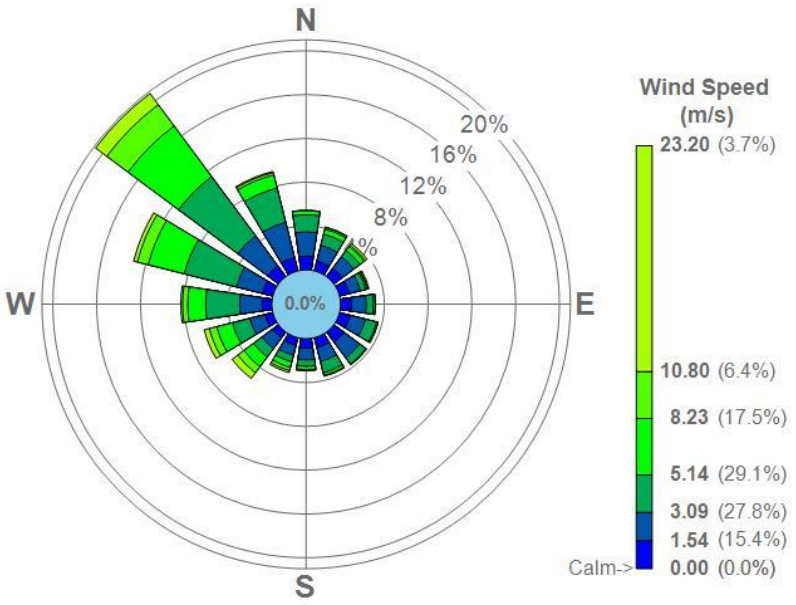
2.1.4 Supporting Activities

Several permitted exhausters within these tank farms will provide abatement for tank waste disturbing activities during waste feed preparation. In addition, other waste retrieval and transfer activities will require supporting exhausters, and sources were placed in A, B, C, and BX Tank Farms. A core sampler will be used before and during retrieval for waste characterization. An exhauster will be used to support this activity. Exhausters will be used to dry the tank out after the tank waste has been retrieved. For this assessment, an exhauster was placed in the A Tank Farm, B Tank Farm, C Tank Farm, and BX Tank Farm, for a total of four tank dry out exhausters.

2.2 HANFORD METEOROLOGY

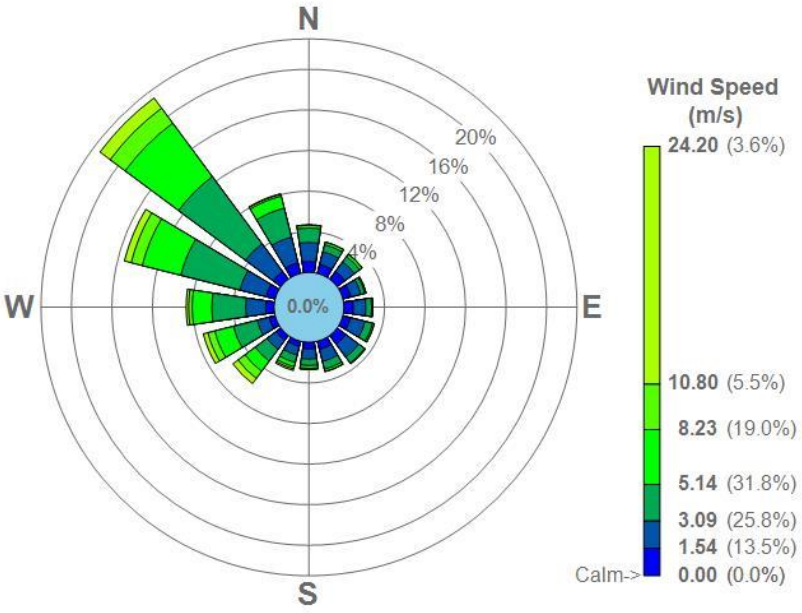
The Hanford Site is in the rain shadow of the Cascade Mountains and receives an average of less than 7-in. of rain per year. The wind is predominately from the west, but calm wind conditions are frequent. Wind roses from the Hanford Meteorological Stations (HMS) for the calendar years 2009 through 2013 are shown in Figures 2 through 6.

Figure 2. Wind Rose for Calendar Year 2009 from the HMS



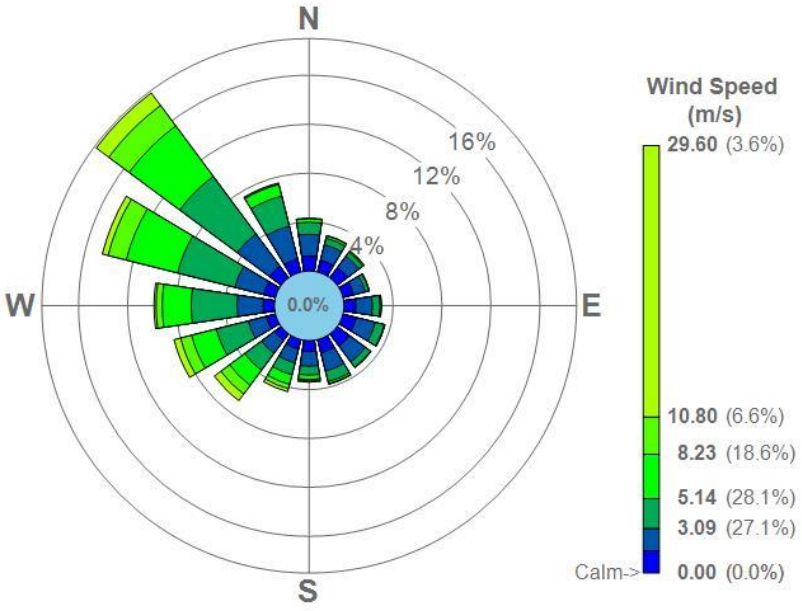
Showing the direction the wind is blowing from, wind speed, and frequency. (1 meter per second equals 2.24 miles per hour)
m/s = meters per second.

Figure 3. Wind Rose for Calendar Year 2010 from the HMS



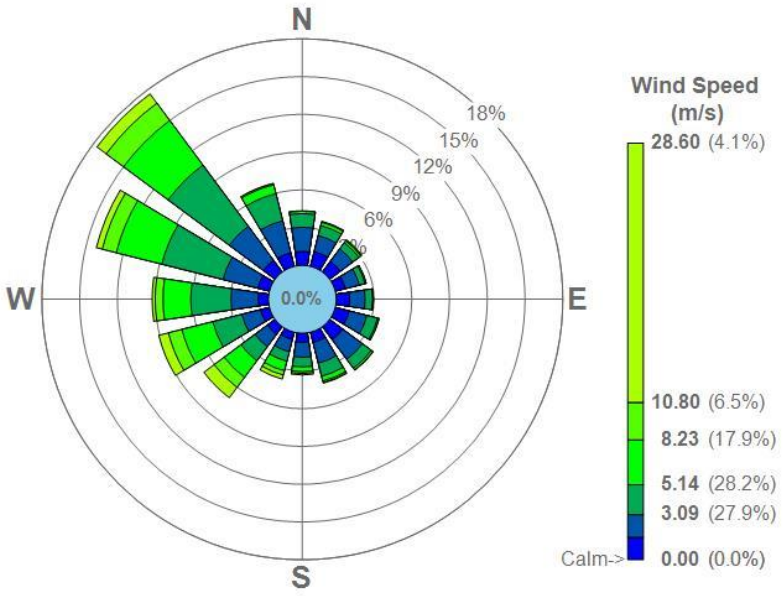
Showing the direction the wind is blowing from, wind speed, and frequency. (1 meter per second equals 2.24 miles per hour)
m/s = meters per second.

Figure 4. Wind Rose for Calendar Year 2011 from the HMS



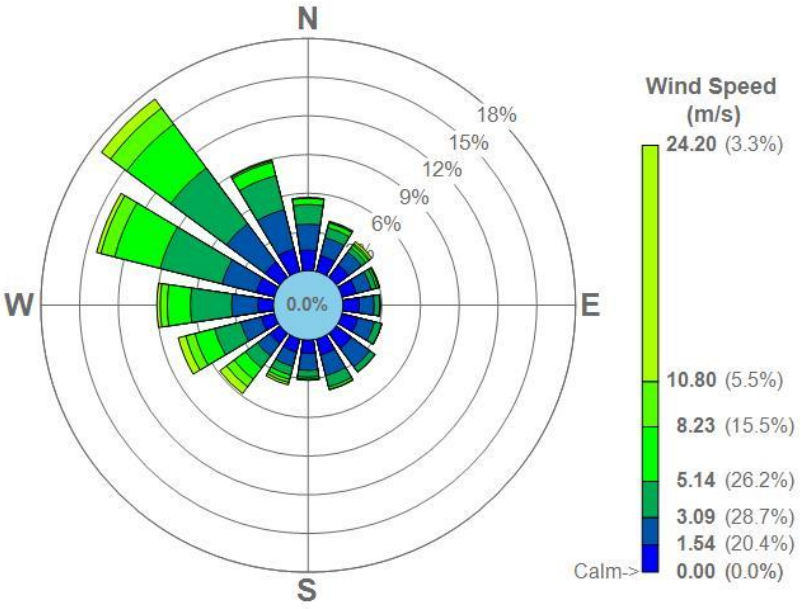
Showing the direction the wind is blowing from, wind speed, and frequency. (1 meter per second equals 2.24 miles per hour)
m/s = meters per second.

Figure 5. Wind Rose for Calendar Year 2012 from the HMS



Showing the direction the wind is blowing from, wind speed, and frequency. (1 meter per second equals 2.24 miles per hour)
m/s = meters per second.

Figure 6. Wind Rose for Calendar Year 2013 from the HMS



Showing the direction the wind is blowing from, wind speed, and frequency. (1 meter per second equals 2.24 miles per hour).
m/s = meters per second.

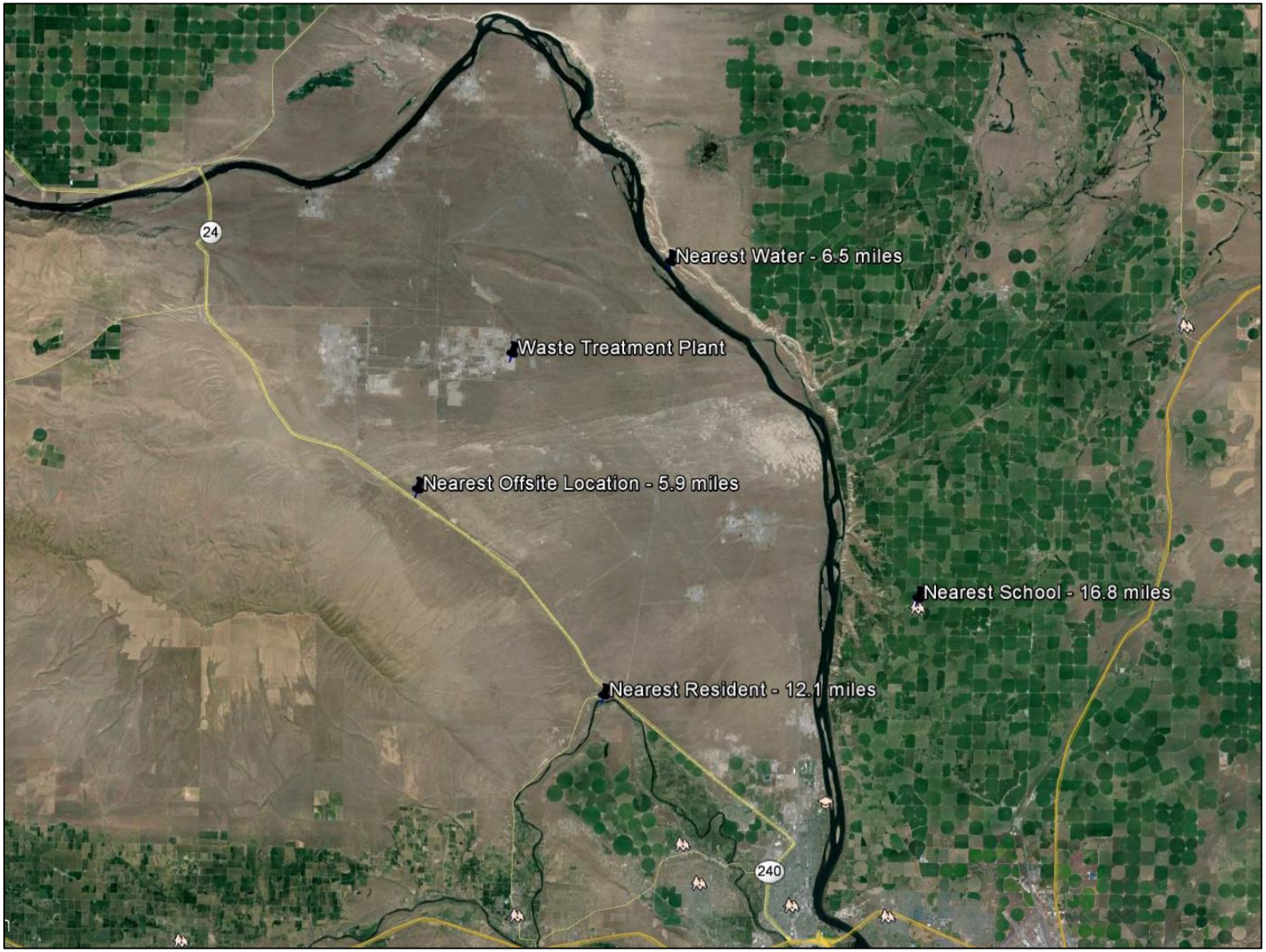
2.3 PUBLIC RECEPTORS

Due to the high contribution from the WTP emissions to the modeled 24-hour highest concentration, the WTP was used as the source center for reporting the distance for each public receptor. Table 2 shows locations of public receptors. Figure 7 shows a map of the public receptors.

Table 2. Locations of Public Receptors

Parameter	Location	Distance from Center of WTP (miles)
Nearest Offsite Location	Highway 240, southwest of the WTP	5.9
Nearest Resident	Junction of Highway 240 and 225, south of the WTP, on bank of Yakima River	12.1
Nearest Water Body	Columbia River, northwest of the WTP	6.5
Nearest School	Edwin Markham Elementary, Pasco, southeast of the WTP	16.8

Figure 7. Map of the Hanford Area with Nearest Public Receptors



3.0 RESPONSIBLE MANAGER

The current responsible facility manager is:

Kevin W. Smith, DOE-ORP Manager
U.S. Department of Energy, Office of River Protection
P.O. Box 450
Richland, Washington 99352
(509) 372-2315

4.0 HAZARD IDENTIFICATION

Hazard identification involves evaluating compound toxicity data and health injury or disease that may occur due to exposure. DMM is a TAP with a very low ASIL level, and is the driver of this HIA. A toxicological review of DMM is provided in Section 4.1. Section 4.2 assesses several other TAPs that are included in this HIA as compounding factors consistent with Ecology's HIA guidance manual since they share similar neurotoxic health impacts and have estimated emissions above their respective SQER levels. Appendix B shows the 68 TAPs that were above the SQER screening level. Of these 68 TAPs, Appendix C provides a toxicological summary of the neurotoxins exceeding the SQER that are considered for inclusion in this assessment.

4.1 DIMETHYL MERCURY

This section summarizes the results of the literature review conducted in support of this HIA.

DMM is an organomercury compound that is very toxic to humans. DMM can cause delayed, permanent brain damage, weakness, impaired hearing, difficulty walking, personality changes, tremors, and death. The primary toxicological endpoint is a non-cancer neurological effect; the most sensitive effect being damage to the fetal central nervous system. A small skin exposure of a few drops has been lethal (Nierenberg, et al. 1998, *Delayed Cerebellar Disease and Death after Accidental Exposure to DMM*). Due to its high toxicity, DMM is rarely used and only a few cases of DMM poisoning have been documented.

DMM is a colorless liquid that is volatile and soluble in water. There are several peer reviewed studies in the literature that report measured levels of it in natural waters. However, its solubility is most likely negligible due to the low air concentrations attributable to the proposed emissions. This is supported by values reported by Conaway, et al. 2010, *Mercury speciation in Pacific coastal rainwater, Monterey Bay, California*, of DMM concentrations below the limit of detection in rainwater, <0.05 pM (and in air, <0.01 ng/m^3).

The physical properties of DMM are shown in Table 3.

Table 3. Physical Properties of DMM

Property*	Value
Melting Point	-43°C
Boiling Point	93-94°C
Density	3.19 g/mL at 20°C

*Patnaik, 2007, *A Comprehensive Guide to the Hazardous Properties of Chemical Substances*.

Due to the scarcity of DMM toxicity data, very few toxicity level recommendations are available. While only a few cases of DMM toxicity have been studied, most have been fatal. Methyl mercury (MeHg) toxicity has been studied more extensively. There are many similarities between DMM toxicity and MeHg toxicity (ACGIH 2001, *Mercury Alkyl Compounds*). DMM is metabolized to MeHg in the human body before it enters the brain (Ostlund 1969, *Studies on the Metabolism of Methyl Mercury in Mice*) and is further converted to inorganic mercury in the brain. Since DMM is metabolized to MeHg, toxicity data from MeHg can be used to estimate the toxicity of DMM. There have been a few cases of MeHg poisoning due to people ingesting MeHg that had bioaccumulated in fish and also from grain tainted with MeHg used as a fungicide (NRC 2000, *Toxicological Effects of Methylmercury*). The toxicity of organomercury compounds is different from inorganic mercury compounds. Organomercury compounds pass through the blood-brain barrier and the placenta very rapidly compared to inorganic mercury compounds (ACGIH 2001).

The National Research Council (NRC) issued *Toxicological Effects of Methylmercury* in 2000 to analyze the literature and develop a reference dose for MeHg for the EPA. Methyl mercury is soluble in water and bioaccumulates up the food chain. There have been documented cases of mass exposure of people to MeHg due to mercury poisoning of water bodies and the subsequent ingestion of fish. Two instances occurred in Japan. There was also a mass poisoning due to the ingestion of MeHg coated wheat in Iraq (NRC 2000).

MeHg is rapidly absorbed from the gastrointestinal tract and accumulates in the adult and fetal brain. Methyl mercury can cross the blood-brain barrier and is also able to cross the placental barrier exposing the fetus. In the brain, the MeHg is slowly converted to inorganic mercury. Animal studies have indicated that the developing nervous system in fetal and young animals is the most sensitive target organ for MeHg exposure. The central nervous system effects are neuronal death leading to impairment of cognitive, motor, and sensory functions. The evidence for MeHg being carcinogenic is inconsistent and inconclusive (NRC 2000).

The NRC determined that the population at the highest risk is children of women who consume large amounts of fish and seafood during pregnancy. The developing brain of the fetus is most susceptible to mercury poisoning. The DMM inhalation reference exposure level, based on MeHg levels, is 1.4E-01 µg/m^3, and the oral reference exposure level is 1.0E-04 mg/kg body weight per day.

4.1.1 Landfill Emissions

Mercury compounds are widely used and they are commonly disposed of in municipal incinerators and landfills. Inorganic mercury under anaerobic conditions common in landfills can be transformed into methylated forms (Compeau and Bartha 1985, “Sulfate Reducing Bacteria: Principle Methylators of Mercury in Anoxic Estuaring Sediments”). Limited studies have been conducted looking at emissions of DMM from landfills. Lindberg et al. (2001), “Methylated Mercury Species in Municipal Waste Landfill Gas Sampled in Florida,” found mean concentrations of 30 ng/m^3 in landfill off gases in Florida. Eight landfills in Washington State were studied and landfill gas concentrations were found to be between 7.1 and 46.1 ng/m^3 (Gallagher and Bennett 2003, “Determination of Total and DMM in Raw Landfill Gas with Site

Screening for Elemental Mercury at Eight Washington State Landfills for the Washington State Department of Ecology").

4.1.2 Atmospheric Background Concentrations

This section will assess the applicability of DMM background concentrations, as required by WAC 173-460-090:

> "(5) Background concentrations of TAPs will be considered as part of a second tier review. Background concentrations can be estimated using:
> (a) The latest National Ambient Toxics Assessment data for the appropriate census tracts; or
> (b) Ambient monitoring data for the project's location; or
> (c) Modeling of emissions of the TAPs subject to second tier review from all stationary sources within 1.5 kilometers of the source location."

To determine the atmospheric background concentrations of DMM for this HIA, option (c) was considered. The Hanford Site is 581 square miles. Based on the remote location and size of the site, there were not any other sources with the potential to emit DMM within 1 mile (1.5 kilometers) of sources on the Hanford Site. All emissions potential within the Hanford Site boundary has already been considered for this HIA. However, details and discussion on DMM background concentration studies have been included for conservatism.

Only a limited number of atmospheric measurements of DMM have been made. Measurements of DMM were made in Antarctica and are shown in Table 4 (de Mora et al. 1993, "Baseline Atmospheric Mercury Studies at Ross Island, Antarctica.")

Table 4. Results from 196 Measurements of Atmospheric DMM in Antarctica

Measurement	Concentration (ng/m^3)
Mean	0.04
Standard Deviation	0.08
Standard Error	0.01
Maximum	0.63
Minimum	0.00

An unknown number of ambient air concentrations in Seattle, Washington, were measured to be 0.003 ± 0.004 ng/m^3 (Prestbo, et al. 1996, *A Global View of the Sources and Sinks for Atmospheric Organic Mercury*). In addition to the Prestbo study, Baya, et al. 2015, "Determination of monomethylmercury and dimethylmercury in the arctic marine boundary layer," sampled air in the Canadian Arctic marine boundary layer and reported finding 3.8 ± 3.1 ($n = 37$) k+ pg/m^3 of DMM. No Hanford Site ambient air DMM measurements were available at the time of this assessment.

Due to very limited data, there are large uncertainties in DMM background concentrations. The peak modeled 24-hour concentration is 5.4 ng/m^3 (Section 5.3), which is much higher than 0.003 ng/m^3 (the closest measured background concentration is Seattle, Washington). The background is minimal compared to the modeled concentration. Adding the background concentration to the assessment is unnecessary, because 1) uncertainties in the modeled concentration are greater than the potential background concentration, and 2) the modeled concentration is highly conservative and can be said to include a minimal potential background concentration.

4.1.3 Atmospheric Fate

Limited data is available about the concentration, fate, and transport of DMM in the atmosphere partly due to the very low concentrations and instrument detection limits. Reaction rate studies have shown that DMM will react with chlorine atoms, the hydroxyl radical, the nitrate radical, ozone, and fluoride radicals (Sommar et al. 1997, "Rate of Reaction Between the Nitrate Radical and DMM in the Gas Phase"). The reactions of DMM and chlorine atoms, hydroxyl radical, and nitrate radical are the most dominant in the atmosphere. Given the atmospheric radical concentrations, the lifetime of DMM in the atmosphere ranges from roughly 1 to 100 hours (Sommar et al. 1997). Table 5 shows the lifetime of DMM in the atmosphere and the reaction products. Based upon this data, the Hg products from the Hanford Site DMM emissions is predicted to remain in the boundary of the Hanford Site. Therefore, none of these other forms of DMM were measured outside the site boundary.

Table 5. Atmospheric Lifetime of DMM and Mercury Containing Products

Oxidant	Lifetime (hours)	Mercury Products	Reference
Cl	1 - 100	CH_3HgCl	Niki et al. 1983
OH	1.2 - 30	None detected	Niki et al. 1983
NO_3	0.8 - 150	Hg or HgO	Niki et al. 1983
Ozone	80,000 – 1,100,000	HgO	Sommar et al. 1996

Cl = chlorine, OH = hydroxyl, NO_3 = nitrate, O_3 = ozone, F = fluoride

4.2 CUMULATIVE IMPACT OF COMPOUNDS SIMILAR TO DMM

Proper development of the nervous system is critical for early learning and can have potentially significant implications for the health of individuals throughout their lifetimes. In order to assess the full health impact of neurotoxic compounds from the Hanford Site, this HIA assesses all TAPs that exceed the SQERs which have similar health effects as DMM. As shown in Appendix B, estimated emissions from the modeled sources exceed the SQER for 68 TAPs. After consultation with Ecology, 13 of these compounds [i.e., arsenic and inorganic arsenic compounds, benzene, cadmium and other cadmium compounds, heptachlor, hexachlorobenzene,

lead and compounds, manganese and compounds, elemental mercury, nitrogen dioxide, perchloroethylene (PCE), polychlorinated biphenyls (PCB), trichloroethylene (TCE), and vinyl chloride (VC)] were determined to be potential neurotoxins with similar interactions with the human body as DMM. Table 6 summarizes the TAP emission rate and the SQER from WAC 173-460-150. The objective of this section is to detail the effects of each compound on the human body and the choice to include it in the calculation of the cumulative effect of these compounds on the nervous system, thus including them in the neurotoxicity hazard index with DMM.

Table 6. Hanford Site TAPs Exceeding the Small Quantity Emission Rate

CAS#	Compound	Emission Rate	SQER
7440-38-2	Arsenic and inorganic arsenic compounds	1.85E-01 lbs/yr[a]	5.81E-02 lbs/yr
71-43-2	Benzene	1.53E+03 lbs/yr	6.62E+00 lbs/yr
7440-43-9	Cadmium and compounds[c]	8.09E-02 lbs/yr[a]	4.57E-02 lbs/yr
593-74-8	Dimethyl mercury	1.07E-04 lbs/24-hr	1E-99 lbs/24-hr
76-44-8[b]	Heptachlor	2.77E+00 lbs/yr	1.48E-02 lbs/yr
118-74-1	Hexachlorobenzene[b]	6.09E-01 lbs/yr	3.76E-01 lbs/yr
7439-92-1	Lead and compounds	1.61E-01 lbs/yr[a]	16E+00 lbs/yr
7439-96-5	Manganese and compounds	4.47E-04 lbs/24-hr[a]	5.26E-03 lbs/24-hr
7439-97-6	Mercury, elemental	7.52E-02 lbs/24-hr	1.18E-02 lbs/24-hr
10102-44-0	Nitrogen dioxide[c]	7.25E+00 lbs/1-hr	1.03E+00 lbs/1-hr
127-18-4	Perchloroethylene	1.62E+03 lbs/yr	3.24E+01 lbs/yr
1336-36-3	Polychlorinated biphenyls	1.91E+01 lbs/yr	3.36E-01 lbs/yr
79-01-6	Trichloroethylene	1.52E+03 lbs/yr	9.59E+01 lbs/yr
75-01-4	Vinyl chloride	1.53E+03 lbs/yr	2.46E+00 lbs/yr

a. HEPA filter abatement applied to particulate metals from Tank Farm sources at a 99.9% removal efficiency. Cadmium and arsenic remained above the SQER and were further analyzed. Lead and manganese fell below the SQER and were not considered for this HIA.
b. Heptachlor and hexachlorobenzene are assumed PICs, as listed on Table A-1 of the EPA 1998, *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. The compounds were not detected in any of the WTP pilot melter testing campaigns, however, EPA's list will continue to be referenced until actual stack testing can be performed. The PICs are incorporated into WTP air permits at estimated quantities for conservatism.
c. Based on the toxicity review provided in Section 4.2, these compounds are recognized in the HIA as having potential neurotoxic effects, but are not included in the calculation of the neurotoxicity hazard index.

4.2.1 Nitrogen Dioxide

Nitrogen dioxide has been detected in both the tank waste and tank emissions at the Hanford Site. Nitrogen dioxide is not included in the computation of the hazard index for this HIA due to lack of neurotoxic specific data, but is discussed for completeness, as further detailed below. Nitrogen dioxide primarily affects the lungs and can cause lung edema at high concentrations (Kim et al. 2014, "Prenatal exposure to PM_{10} and NO_2 and children's neurodevelopment from birth to 24 months of age: Mothers and Children's Environmental Health [MOECH] Study.") In addition, maternal nitrogen dioxide exposure has been related to impairment of psychomotor development. Kim et al. (2014) found significant effects of prenatal nitrogen dioxide exposure on mental developmental at 6 months, but no significant association was found at 12 and 24 months of age.

Although there are studies that indicate a potential for nitrogen dioxide to act as a neurotoxin, the reference exposure limits are not based on neurotoxicity. Therefore, it is impossible to quantify the nitrogen dioxide hazard. Based on toxicity research, nitrogen dioxide could increase the total neurotoxic hazard of the compounds assessed in this HIA by an inestimable amount.

The nitrogen dioxide modeled air concentration on the highest 24-hour DMM day is 2.4E-01 $\mu g/m^3$. No deposition modeling was completed for nitrogen dioxide.

4.2.2 Hexachlorobenzene

Hexachlorobenzene (HCB) has not been detected in the tank waste or tank emissions at the Hanford Site. It is included in this HIA based on its inclusion in existing WTP air permits. HCB is an assumed PIC (product of incomplete combustion), as listed on Table A-1 of EPA 1998, "Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities." It was not detected in any of the WTP pilot melter testing campaigns, however, EPA's list will continue to be referenced until actual stack testing can be performed. The PICs are incorporated into WTP air permits at estimated quantities for conservatism.

HCB is a highly lipophilic compound and a ubiquitous environmental pollutant that was once used as a fungicide. The major route of human exposure to HCB today is probably as a contaminant in the diet. HCB in the blood stream readily accumulates in fat tissue, and is a common residue detected in human fat tissue samples. Developmental exposure to HCB occurs via placental and lactational transfer. During pregnancy, systemic HCB crosses the placenta in both humans and mice. Concentrations of HCB in fetal blood and maternal blood are similar. Fetuses and neonates may be more susceptible to the effects of HCB than adults because their lower body fat allows HCB to circulate in the blood and lean tissues for long periods and because HCB can easily cross the blood-brain barrier, particularly before this barrier is completely developed. Goldey, et al. (1992), "Developmental neurotoxicity following premating maternal exposure to hexachlorobenzene in rats," exposed fetuses to low levels of HCB via placental transfer and exposed neonates to large quantities of HCB via the milk. The concentration of HCB in the neonates declined following weaning, and HCB was not detectable in tissues of mature offspring. However, the results of behavioral testing indicate that HCB affects multiple pathways throughout the developing nervous system.

HCB is an assumed neurotoxin with reference exposure limits based on neurotoxic effects on the human body. HCB is included in the computation of the hazard index. On the highest 24-hour DMM day, the HCB modeled air concentration is 3.8E-06 µg/m^3 and the modeled deposition rate is 2.5E-05 µg/m^2.

4.2.3 Perchloroethylene

PCE, or tetrachloroethylene, has been detected in both the tank waste and tank emissions at the Hanford Site.

PCE is a solvent used in the dry cleaning industry. Neurotoxicity via PCE is recognized as the major non-cancer toxicologic endpoint (Kathryn, et al. 2014, "Human Health Effects of Tetrachloroethylene: Key Findings and Scientific Issues"). PCE can be transferred to an infant through breast milk; however exposure levels are usually attributed to inhalation. PCE induces the neurotoxicity by direct action, whereas most other compounds that target organ toxicity are dependent on metabolic activation by mixed function oxidase. PCE is thought to effect dopamine levels in the brain. Studies suggest that the period of synaptogenesis, late pregnancy through early infancy, may be the most sensitive period of development of the adverse effects of PCE. Altmann et al. 1995, "Neurobehavioral and neurophysiological outcome of chronic low-level tetrachloroethene exposure measured in neighborhoods of dry cleaning shops," found a significant decrement in tests for vigilance, simple reaction time, and visual memory in exposed individuals.

PCE is a well-documented neurotoxin with reference exposure limits based on neurotoxic effects on the human body. PCE is included in the computation of the hazard index. On the highest 24-hour DMM day, the HCB modeled air concentration is 7.1E-03 µg/m^3 and the modeled deposition rate is 3.6E-03 µg/m^2.

4.2.4 Polychlorinated Biphenyls

PCBs have been detected in both the tank waste and tank emissions at the Hanford Site.

PCBs are synthetic organic chemicals that persist in the environment for decades. PCBs persist in human tissues, having half-lives of about 7 years. Therefore, offspring of females exposed to PCBs continue to be born affected, even though maternal exposure might have ceased. In a study done by Rogan, et al. 1988, "Congenital poisoning by polychlorinated biphenyls and their contaminants in Taiwan," children from exposed mothers had a lower birth weight, hyperpigmentation, conjunctivitis, nail changes, and natal teeth. There were no abnormal reflexes or any localized findings in the neurological exam; however, the exposed children were delayed compared to controls in the age at which they performed tasks, such as saying phrases and sentences, turning pages, carrying out requests, pointing to body parts, holding pencils, imitating drawn circles, or catching a ball. The exposed children always scored lower than the controls on the developmental and cognitive tests.

Effects of PCBs on nervous system development have been studied in monkeys and a variety of other animal species. Newborn monkeys exposed to PCBs showed persistent and significant deficits in neurological development, including visual recognition, short-term memory and learning. Some of these studies were conducted using the types of PCBs most commonly found in human breast milk. In the paper *Public Health Implications of Exposure to Polychlorinated Biphenyls (PCBs)*, the EPA notes that in various human health studies neurobehavioral and developmental deficits occur in newborns and continue through school-aged children who had in utero exposure to PCBs.

Although PCBs are documented as being potential neurotoxins, the reference exposure limits were not computed based on neurotoxic effects. PCBs are not included in the computation of the hazard index. However, the potential health risk of PCBs from the Hanford Site was assessed. On the highest 24-hour DMM day, the PCB modeled air concentration is 8.9E-05 $\mu g/m^3$. No deposition modeling was completed for PCBs. The inhalation reference concentration is 1.3E+00 $\mu g/m^3$. The modeled air concentration is well below the inhalation reference concentration; therefore, indicating PCBs from Hanford Site emissions are an unlikely health risk to the public.

4.2.5 Benzene

Benzene has been detected in both the tank waste and tank emissions at the Hanford Site.

Benzene exists mostly in the vapor phase. It reacts with photochemically produced hydroxyl radicals with a calculated half-life of 13.4 days. In atmospheres polluted with nitrogen oxide or sulfur dioxide, the half-life can be as short as 4 to 6 hours. Acute, high inhalation exposure may lead to eye, nose, and throat irritation and central nervous system depression in humans. The non-cancer adverse health effects of benzene results from the ability of its metabolites to adversely affect rapidly dividing cells. Children may be more sensitive to benzene because so many of their tissues are undergoing rapid cell division and differentiation for growth and development to stimulate and maintain growth. Benzene itself is neurotoxic, but its metabolites have other toxic properties. The benzene metabolites are found to be preferentially retained in the bone marrow. The metabolites are not readily excreted, and are cytotoxic to the stem cells in the bone marrow.

Several days of acute exposure to benzene caused neurotoxic symptoms in 11 of 15 workers (Midzenski, et al. 1992, "Acute high dose exposure to benzene in shipyard workers"). Eighty percent of children exposed to benzene reported neurological problems (unsteady gait, memory loss, headaches) (D'Andrea and Reddy 2013, "Health Effects of Benzene Exposure among Children Following a Flaring Incident at the British Petroleum Refinery in Texas City"). Based on blood samples taken at birth from mother and infant, benzene can cross the human placenta and be in the umbilical cord at a level equal to or greater than in maternal blood (Dowty, et al. 1976, "The transplacental migration and accumulation in blood of volatile organic constituents"). An exposure of 500 ppm benzene for 7 hours per day through days 6-15 of gestation was teratogenic in the fetal brain of rats (Lo Pumo, et al. 2006, "Long-lasting neurotoxicity of prenatal benzene acute exposure in rats"). It was concluded that acute exposure to benzene

during gestational organogenesis may cause long-lasting changes in motor behavior during cognitive processes.

Benzene is a well-documented neurotoxin with reference exposure limits based on neurotoxic effects on the human body. Benzene is included in the computation of the hazard index. On the highest 24-hour DMM day, the benzene modeled air concentration is 7.1E-03 µg/m^3 and the modeled deposition rate is 9.2E-04 µg/m^2.

4.2.6 Arsenic and Inorganic Arsenic Compounds

Arsenic and other inorganic arsenic compounds have been detected in both the tank waste and tank emissions at the Hanford Site.

Arsenic is found in small amounts in soil, water, and food. It is a product of ore refining processes, smelting of copper/lead, pesticides, and wood preservatives. Inorganic arsenic metabolizes into trivalent methylated species, which are thought to be more toxic than inorganic forms and may play a role in arsenic toxicity for selected endpoints. Arsenic is readily absorbed by the human body, at between 54% and 80%. The liver is the site of methylating activity. The gastrointestinal tract is the predominant route of exposure. Calderon et al. 2001, "Exposure to arsenic and lead and neuropsychological development in Mexican children" found verbal intelligence quotient, language, comprehension, and long-term memory were observed to decrease in children with increasing urinary arsenic. Itoh et al. 1990, "The effect of arsenic trioxide on brain monoamine metabolism and locomotor activity of mice," indicated an effect of arsenite on brain chemistry. Frank 1976, "Neurological and psychiatric disorders following acute arsine poisoning," found that central and peripheral nervous systems may be affected by acute arsine exposure, leading to agitation, disorientation, and other symptoms.

Arsenic and other inorganic arsenic compounds are well-documented neurotoxins with reference exposure limits based on neurotoxic effects on the human body. It is included in the computation of the hazard index. On the highest 24-hour DMM day, the arsenic modeled air concentration is 6.6E-07 µg/m^3. The deposition rate, 1.1E-03 µg/m^2, was calculated using a Hot Spots calculation.

4.2.7 Cadmium and Other Cadmium Compounds

Cadmium and other cadmium compounds have been detected in both the tank waste and tank emissions at the Hanford Site.

Cadmium does not normally reach the brain, but the brain barrier can be damaged when saturation is reached and cause severe effects on the central nervous system (Parkinson-like symptoms) (Wang and Du 2013, "Cadmium and Its Neurotoxic Effects"). Only acute, high doses of cadmium are shown to have an effect on the brain. Cadmium can pass to the fetus via the placenta.

Although cadmium is considered a potential neurotoxin, it does not have chronic health effects, like DMM. Cadmium was not included in the calculation of the hazard index for this HIA. The

emission rate of 8.09E-02 lbs/yr is only slightly above the SQER, and the modeled concentration was well below the reference exposure limit (REL). The central nervous system is not a hazard index target organ for the REL. The cadmium modeled air concentration, 3.3E-07 µg/m^3, is well below the chronic inhalation level of 2.0E-02 µg/m^3. No deposition modeling was completed for cadmium.

4.2.8 Vinyl Chloride

Vinyl Chloride (VC) has been detected in both the tank waste and tank emissions at the Hanford Site.

VC is used in the production of polyvinyl chloride resins used for plastic piping. Thermal decomposition of VC produces hydrogen chloride, carbon monoxide, and traces of phosgene. The primary acute physiological effect of VC inhalation is central nervous system depression. VC is metabolized to form its toxic metabolites. Acute exposure to VC can cause death due to respiratory failure. Mastromatteo, et al. 1960, "Acute inhalation toxicity of vinyl chloride to laboratory animals," found that exposure to VC resulted in increased motor activity, muscular incoordination, unsteady gait, and pronounced tremor. Ungvary, et al. 1978, "Effects of vinyl chloride exposure alone and in combination with trypan blue–applied systematically during all thirds of pregnancy on the fetuses of CFY rats," found exposure to VC during all three trimesters of pregnancy did not result in an increased incidence of birth defects. However, VC did cross the placental barrier and was present in the fetal blood. Quan, et al. 2014, "Vinyl chloride monomer (VCM) induces high occurrence of neural tube defects in embryonic mouse brain during neurulation" found that doses higher than 400 mg/kg of VC increased the incidence of malformed embryos, especially neural tube defects.

Although VC is considered a potential neurotoxin, it does not have chronic health effects, like DMM. VC was not included in the calculation of the hazard index for this HIA. However, the potential health risk of VC from the Hanford Site was assessed. On the highest 24-hour DMM day, the VC modeled air concentration is 1.4E-01 µg/m^3. The VC acute inhalation reference exposure level is 1.0E+02 µg/m^3. No deposition modeling was completed for VC.

4.2.9 Heptachlor

Heptachlor has only been detected in ETF emissions at the Hanford Site. It is also an assumed PIC, as listed on Table A-1 of EPA (1998). It was not detected in any of the WTP pilot melter testing campaigns, however, EPA's list will continue to be referenced until actual stack testing can be performed. The PICs are incorporated into WTP air permits at estimated quantities for conservatism.

Heptachlor is an organochlorine compound used as a pesticide. Mouse model studies have suggested that exposures to heptachlor induced changes in the expression of dopamine transporters, which may alter the susceptibility of dopaminergic neurons to other Parkinson disease-promoting neurotoxins. Heptachlor can act as a direct neurotoxin on the dopaminergic neurons in the substantia nigra. Hong et al., 2014, "Heptachlor induced nigral dopaminergic neuronal loss and Parkinsonism-like movement deficits in mice," observed a selective loss of

dopaminergic neurons as well as gliosis in the substantia nigra when heptachlor was injected (twice a week for 8 weeks) into mice on a subchronic schedule. Deficits in motor function were also observed. Developmental studies have found neurological and immunological effects in offspring.

Although most of the Hanford Site heptachlor emissions are estimates for conservatism, heptachlor is a well-documented neurotoxin with reference exposure limits based on neurotoxic effects on the human body. Therefore, it is included in the computation of the hazard index. On the highest 24-hour DMM day, the heptachlor modeled air concentration is 1.7E-05 $\mu g/m^3$, and the modeled deposition rate is 1.1E-04 $\mu g/m^2$.

4.2.10 Trichloroethylene

Trichloroethylene (TCE) has been detected in both the tank waste and tank emissions at the Hanford Site.

TCE is a widespread contaminant in drinking water due to it being water soluble. TCE has widespread bodily effects; however, no strong support for teratogenic behaviors. Noland-Gerbec 1986, "2-Deoxyglucose uptake in the developing rat brain upon pre- and postnatal exposure to trichloroethylene," found that animals exposed to TCE have a decrease in glucose uptake/metabolism in the brain. Chronic exposure in the workplace has been associated with damage to cranial nerves in several studies. Sanz, et al., 2008, "Myoclonic encephalopathy after exposure to trichloroethylene," reported a case of chronic TCE exposure with persistent neurological symptoms. Goldman, et al., 2012, "Genetic Modification of the Association of Paraquat and Parkinson's Disease," found that over exposure to TCE was associated with a significantly increased risk of Parkinson disease. No increase in malformed babies was observed among parents exposed to TCE in the workplace (Tola et al., 1980, "A cohort study on workers exposed to trichloroethylene.").

Although neurotoxic effects on the fetus are not well documented, TCE is a well-documented neurotoxin with reference exposure limits based on neurotoxic effects on the human body. Therefore, it is included in the computation of the hazard index. On the highest 24-hour DMM day, the TCE modeled air concentration is 7.1E-03 $\mu g/m^3$, and the modeled deposition rate is 1.2E-03 $\mu g/m^2$.

5.0 EMISSIONS AND ATMOSPHERIC MODELING

The methodology for determining emissions for each source is described below. Atmospheric modeling was conducted to estimate ambient concentrations, as recommended by Ecology.

5.1 EMISSIONS

The conservative emission rates were developed to bound all future activities at the Hanford Site, while keeping the scenario general enough that many activities could be assumed to be accounted for within the HIA. It is assumed that the modeled scenario is highly conservative and will cover most, if not all, future activities on the Hanford Site (e.g., one or more waste disturbing activities in a single tank farm, full operation of the WTP while multiple waste disturbing activities take place in tank farms, multiple waste retrieval activities). The sources chosen to represent hypothetical emissions from these activities are representative of the potential DMM emissions across the Hanford Site, and are not the only sources on the Hanford Site.

5.1.1 Tank Farms

The unabated emissions of criteria pollutants from all tank farm ventilation systems was estimated based upon measured headspace concentrations documented in the Tank Waste Information Network System (TWINS) database. The TWINS database was searched for regulated criteria pollutants and TAPs by the Chemical Abstracts Service number for each pollutant. Because waste transfers will occur between tanks during the lifetimes of the ventilation systems, the highest emission rate per tank was calculated. The maximum per tank emission rate was used for each farm and it was assumed that one of the tanks will be mixed. Emissions of all TAPs are shown in Appendix B.

Assumptions made for tank farm emissions for this assessment include the following.

- When the maximum value in the TWINS database is the measurement detection limit, that value is assumed to be the reported value.
- Measurements were made over a quiescent waste with the tank passively ventilated for all SSTs and actively ventilated for DSTs. A constant emission rate was assumed as long as the tank waste remains quiescent.
- The headspace concentrations increased by a factor of 100 during waste disturbing activities.
- The highest emission rate from any given tank for each TAP is assumed contained in all tanks in the SST and DST tank farms.

5.1.2 Waste Treatment and Immobilization Plant

The DMM emission rates are documented in 24590-WTP-RPT-PO-03-008, "Integrated Emissions Baseline Report for the Hanford Tank Waste Treatment and Immobilization Plant." The emission rates for the other neurotoxins of concern are documented in 24590-WTP-RPT-ENV-01-009, "Nonradioactive Air Emission Notice of Construction Permit Application for Hanford Tank Waste Treatment and Immobilization Plant." All emission rates are assumed as stated.

Assumptions made for WTP emissions for this assessment include the following.

- The elemental mercury emission rates were assumed for DMM because no DMM emission rates were available. Use of the elemental mercury emission rates over-estimates the amount of DMM expected from the process, thus making this assumption a highly conservative estimate. In order to avoid duplication of this conservative assumption, modeling for elemental mercury as a compounding neurotoxin excluded emissions from the WTP.

- The WTP Laboratory (LAB) and EMF emissions were assumed at the PT emission rate.

5.1.3 Low Activity Waste Pretreatment System

All emission rates for LAWPS were assumed at the single tank flux emission rates as documented in TWINS, and further detailed in Section 5.1.1.

5.1.4 Effluent Treatment Facility

All emission rates for ETF are documented in the Notice of Construction Approval Order #DE07NWP-003. All emission rates are assumed as stated.

5.1.5 242-A Evaporator

All emission rates for the 242-A Evaporator were assumed at the single tank flux emission rates as documented in TWINS, and further detailed in Section 5.1.1.

5.1.6 Core Sampler and Drying Out Exhausters

All emission rates for the core sampler and drying out exhausters were assumed at the single tank flux emission rates as documented in TWINS, and further detailed in Section 5.1.1.

5.1.7 Summary of Emission Rates

Source emission rates were determined as follows. All source emission rates for DMM were increased by an additional factor of 100 for atmospheric modeling (Section 5.3 and 5.4).

Modeled source emission rates for all other neurotoxic compounds were assumed at the rate detailed below.

- The 241-AN Tank Farm emissions were multiplied by a factor of 106 to reflect one tank being mixed and six tanks quiescent.
- The 241-AP Tank Farm emissions were multiplied by a factor of 107 to reflect one tank being mixed and seven tanks quiescent.
- The 241-AY/AZ Tank Farm emissions were multiplied by a factor of 103 to reflect one tank being mixed and three tanks quiescent.
- The 241-AW Tank Farm emissions were multiplied by a factor of 105 to reflect one tank being mixed and five tanks quiescent.
- The 241-AX Tank Farm emissions were multiplied by a factor of 103 to reflect one tank being mixed and three tanks quiescent.
- The 241-A Tank Farm emissions were multiplied by a factor of 103 to reflect one tank being mixed and three tanks quiescent.
- The 241-S Tank Farm emissions were multiplied by a factor of 103 to reflect one tank being mixed and three tanks quiescent.
- The 241-SY Tank Farm emissions were multiplied by a factor of 102 to reflect one tank being mixed and two tanks quiescent.
- The 241-SX Tank Farm emissions were multiplied by a factor of 103 to reflect one tank being mixed and three tanks quiescent.
- The drying out exhausters, core sampler, LAWPS, WTP, ETF, and the 242-A Evaporator emissions were multiplied by a factor of 1.

5.2 BEST AVAILABLE CONTROL TECHNOLOGY

Pursuant to WAC 173-460-060(2), “Control Technology Requirements,” an analysis of best available control technology for toxics (tBACT) for emissions of toxic pollutants was performed, as detailed in RPP-ENV-46679, “Evaluation of Best Available Control Technology for Toxics (tBACT) Double-Shell Tank Farms Primary Ventilation Systems Supporting Waste Transfer Operations,” which was provided to Ecology with previous DMM HIAs.

In summary, a tBACT analysis was performed using the “top-down” approach established for best available control technology (BACT). This approach is defined in detail in EPA 1990, “New Source Review Workshop Manual – Prevention of Significant Deterioration and Nonattainment Area Permitting.” The approach consists of the following steps:

1. Identify all control technologies
2. Eliminate technically infeasible options
3. Rank remaining control technologies by control effectiveness
4. Evaluate most effective controls and document results
5. Select BACT.

Toxics with similar chemical and physical properties were grouped together with the assumption that similar control technologies would be effective. The four groups identified were:

- Ammonia
- Toxic organic compounds
- Mercury and mercury related compounds
- Particulate metal compounds.

A detailed evaluation of the emission control technologies was performed, and after an effectiveness analysis, a cost per ton of pollutant removed was calculated. All of the costs per ton were above $223,000 per ton which exceeded the cost ceiling estimates of $10,500 previously approved by Ecology and EPA for the Hanford Site as economically justifiable (RPP-ENV-46679). Due to the low emission rates, the cost per ton to remove the pollutants becomes prohibitively expensive.

Based upon the results of this tBACT, the proposed tBACT control technology for the DST primary ventilation system consists of a moisture de-entrainer, heater, pre-filter, and two banks of nuclear grade high efficiency particulate air filters in series.

5.2.1 Particulate Metal Compound Abatement in This Assessment

The total unabated Hanford Site emissions of lead and manganese from the modeled sources in this HIA exceed the WAC 173-460-150 SQER levels. In order to accurately portray the emissions of these compounds, and to bring them below the SQER level, the approved particulate metal compound abatement technology was applied to the emissions of these compounds. As described in Section 5.2 of this assessment and RPP-ENV-46679, emission control technology options for particulate metal compounds was evaluated. A control technology consisting of pre-filters, mist eliminators, and dual high efficiency particulate air filters provides a 99.99% mass based removal of metal aerosols. In order to decrease the expected ambient concentration and provide a more accurate concentration, a 99.99% removal efficiency based on filter train control technology was applied.

5.3 AIR DISPERSION MODELING

Ambient air concentrations at the Hanford Site boundary and beyond were estimated using the EPA American Meteorology Society/Environmental Protection Agency Regulatory Model (AERMOD) dispersion model, Version 14134 and 15181. EPA-454/B-03-001, “User’s Guide

for the AMS/EPS Regulatory Model – AERMOD" and Ecology's 08-02-025 HIA guidance manual were used as modeling guidance.

The model inputs included the physical parameters of each stack (Table 10), facility property line, and digital elevation maps. The surface meteorological inputs were from the HMS and the upper air data was obtained from the Spokane, Washington, National Weather Service. Both sets of weather data have previously been checked for quality and used for modeling on the Hanford Site. The calendar years 2009 through 2013 were analyzed. Terrain data was from the U.S. Geological Survey for the surrounding area. The regulatory default mode was used for atmospheric concentrations. Atmospheric deposition factors are described in Section 5.4.

The receptor grid spacing is shown in Table 7.

Table 7. Ecology Recommended Receptor Grid Spacing

Distance from Source (m)	Grid Spacing (m)
0 – 350	10
350 – 800	25
800 – 4,000	50
4,000 – 8,000	100
8,000 – 30,000	200

5.3.1 Modeling Assumptions

- Only offsite receptors were modeled for this analysis, as shown in Figure 1.
- All emission sources were modeled simultaneously, assuming waste disturbing activities were occurring in one tank in each tank farm.
- All sources were assumed to be operating for the entire year to ensure the worst case situation would be modeled for 24-hour concentration.
- From the baseline emission rates detailed in Section 5.1, DMM rates were increased by an additional factor of 100 to model for a Hanford Site worst-case bounding scenario.
- Only DMM was modeled for the full 5 years in order to determine the 24-hour high concentration over a 5-year period. To determine the compounding effects of other neurotoxins with estimated emissions exceeding the SQER (Section 4.2), the other neurotoxins were modeled on the peak 24-hour DMM day.

5.3.2 Air Modeling Results

The receptor with highest 24-hour modeled concentration for DMM was 5.4E-03 µg/m^3 in 2010, as shown in Figure 8, along the southcentral border south of the Hanford Site boundary and west of Highway 225 and the Yakima River. The nearest resident is 2.5 miles to the west of the 24-hour modeled high concentration. For conservatism, the calculations done for the 70-year resident exposure scenario used the 24-hour high concentration and deposition data. See Table 11 for modeling output data.

5.4 DEPOSITION MODELING

DMM and the other neurotoxins of concern can deposit on vegetation and soil, which can then be ingested. In order to quantify an ingestion dose, deposition was modeled. Only gaseous deposition was modeled. Based on a very low average annual rain fall, wet deposition was assumed negligible. The model inputs included the physical parameters of the stack (Table 10), also as required for air dispersion modeling. The AERMOD default options for gaseous dry deposition were used. AERMOD also requires seasonal parameters (Table 8), surface characteristics, and gas physical parameters to model deposition.

Table 8. Regional Seasonal Categories for Dry Deposition Modeling at the Hanford Site

Month	Seasonal Category
January-February	Late autumn after frost or winter with no snow
March-April	Transitional spring with partial green coverage or short annuals
May-August	Midsummer with lush vegetation
September-October	Autumn with unharvested cropland
November-December	Late autumn after frost or winter with no snow

The AERMOD land use category chosen to calculate dry deposition for this region was “rangeland” due to the dominance of shrub steppe in the area.

The transport and cycling of pollutants in the atmosphere are dependent on the physical properties of the pollutant. AERMOD dry deposition requires physical parameters (Table 9) of the gas: diffusivity in air, diffusivity in water, leaf cuticular resistance, and Henry’s Law constant.

Table 9. Compound Specific Deposition Parameters for AERMOD Deposition Modeling

	Diffusivity in Air[a] (cm^2/s)	Diffusivity in Water[a] (cm^2/s)	Cuticular Resistance[b] (s/m)	Henry's Law Constant[b] ($Pa\text{-}m^3/mol$)
Arsenic[c]	Not Available	Not Available	Not Available	Not Available
Benzene	8.80E-02	9.80E-06	2.51E+04	5.57E+02
Dimethyl mercury	6.00E-02	5.25E-06	1.00E+07	6.00E-06
Heptachlor	1.12E-02	5.69E-06	4.03E+02	3.53E+02
Hexachlorobenzene	5.42E-02	5.91E-06	4.03E+02	1.31E+02
Mercury, Elemental	3.07E-02	6.30E-06	1.00E+07	1.50E+02
Perchloroethylene	7.20E-02	8.20E-06	6.04E+03	2.69E+03
Trichloroethylene	7.90E-02	9.10E-06	1.88E+04	1.18E+03

a. U.S. Environmental Protection Services, Soil Screening Guidance. www.epa.gov/superfund/health/conmedia/soil/pdfs/part_5.pdf

b. Wesely, et al., 2002 "Deposition parameterizations for the Industrial Source Complex (ISC3) Model".

c. No deposition values were found for Arsenic. The California EPA Air Toxics Hot Spots Guidance Manual, February 2015, B=modeled air concentration*.02 m/s*86,400, was used to calculate the deposition rate.

5.4.1 Deposition Modeling Results

The peak 24-hour DMM deposition rate was 9.0E-07 g/m^2 per day in 2010, as shown in Figure 9. The location of the peak deposition point is at the Hanford Road and Glade North Road junction, approximately 3 miles west of Energy Northwest. For conservatism and to maintain consistency with the air dispersion exposure calculations, the calculations done for the 30-year and the 70-year resident exposure scenario used the 24-hour high deposition rate. See Table 11 for modeling output data for all compounds.

Table 10. AERMOD Source Inputs

Source ID	Description	UTM		Elevation (m)	Release Height (m)	Stack Height (m)	Stack Temp (K)	Stack Velocity (m/s)	Stack Diameter (m)
		East (m)	North (m)						
AN_STACK	AN Farm Stack	307090	5158942	206.3	8.57	8.57	298	28.02406	0.254
AP_STACK	AP Farm Stack	307266	5158347	209.74	12.19	12.19	298	28.02406	0.254
AW_STACK	AW Farm Stack	307060	5158361	203.9	8.57	8.57	298	28.02406	0.254
AY_STACK	AY/AZ Farms Stack	307010	5158827	207.09	12.19	12.19	298	28.02406	0.254
AX_STACK	AX Farm Stack	306987	5158633	212	15.24	15.24	298	28.01999	0.254
A_STACK	A Farm Stack	307063	5158760	210	15.24	15.24	298	28.01999	0.254
S_STACK	S Farm Retrieval	298367	5157304	204	15.24	15.24	298	28.024	0.254
SY_STACK	SY Farm Stack	298523	5157467	205.17	12.19	12.19	298	23.2876	0.254
SX_STACK	SX Farm Retrieval	298465	5157085	203	15.24	15.24	298	28.024	0.254
EVAP	Evaporator Stack	307070	5158520	213	20.12	20.12	315	6.98	0.203
ETF_STK	ETF Stack	307520	5160066	182	15.54	15.54	295.15	9.11	1.83
LAWPS	LAWPS Stack	307604	5158427	206	18.29	18.29	298	14.9	0.635
PT_S4	PTF Stack - WTP	307988	5158355	194.2	60.96	60.96	310.93	28.75279	0.9144
LV_S3	LAW Stack - WTP	308047.7	5158256	192.6	60.96	60.96	338.71	20.52319	0.4572
HV_S3A	HLW Stack A - WTP	307865	5158234	195.4	60.96	60.96	408.15	13.96999	0.3048

Table 10. AERMOD Source Inputs

Source ID	Description	UTM		Elevation (m)	Release Height (m)	Stack Height (m)	Stack Temp (K)	Stack Velocity (m/s)	Stack Diameter (m)
		East (m)	North (m)						
HV_S3B	HLW Stack B - WTP	307865	5158234	195.4	60.96	60.96	408.15	13.96999	0.3048
LB_S1	LAB Stack - WTP	308094.5	5158441	192	36	36	308.15	18	1.52
EMF_STK	EMF Stack - WTP	308157	5158507	190	36	36	308.15	18	1.52
CORE_SPL	Core Sampler A Farm	307037	5158594	212	6.096	6.096	293	3.105	0.1524
A_DRYOUT	A Farm Drying Out	307050	5158827	212	12.192	12.192	293	3.105	0.1524
B_DRYOUT	B Farm Drying Out	305560	5159912	200	6.096	6.096	293	3.105	0.1524
C_DRYOUT	C Farm Drying Out	306846	5159170	200	12.192	12.192	293	3.105	0.1524
BX_DRYOUT	BX Farm Drying Out	305361	5159969	201	6.096	6.096	293	3.105	0.1524

Figure 8. Contour Map of Modeled 24-Hour High Concentration for Dimethyl Mercury

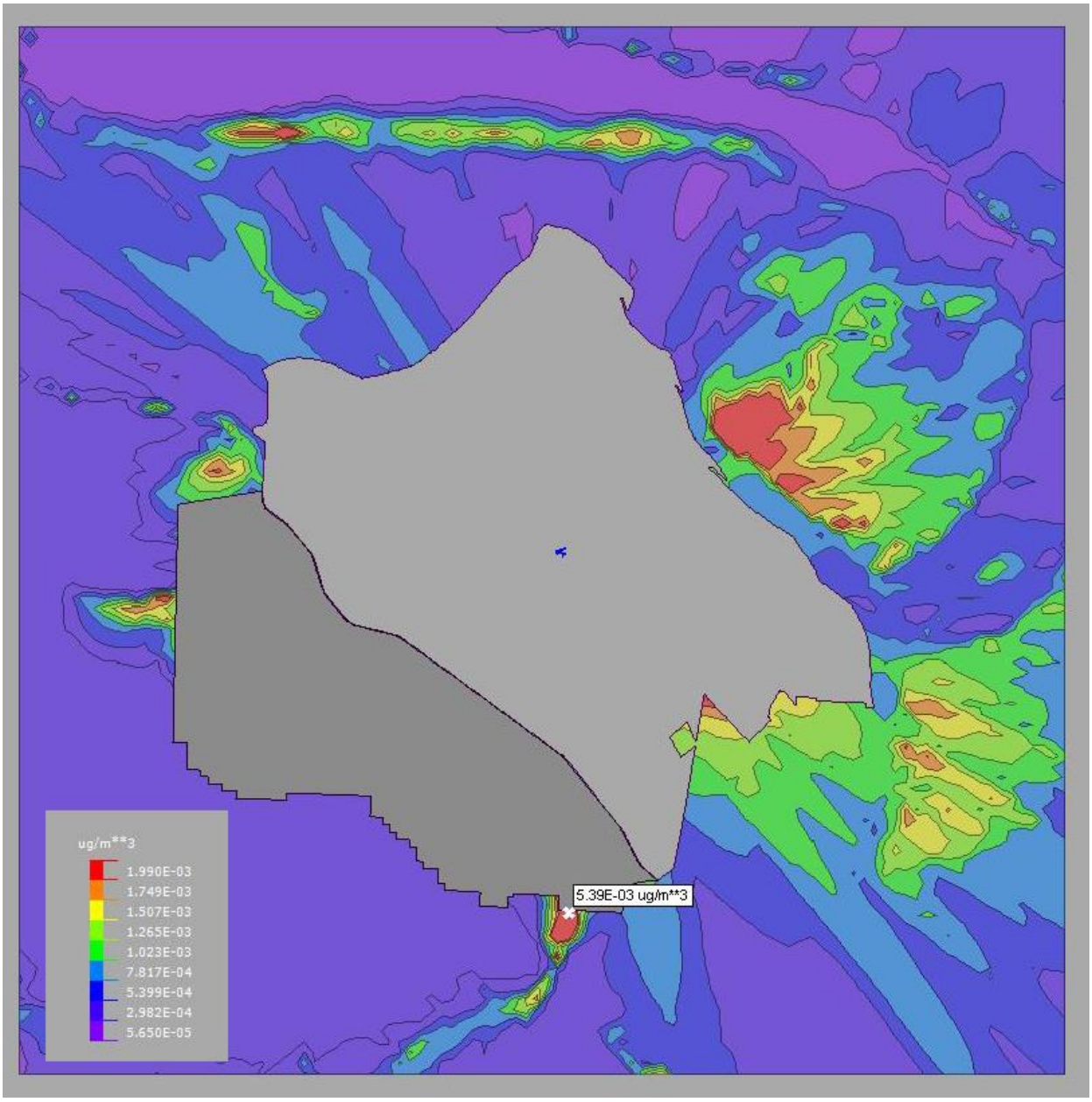


Figure 9. Contour Map of Modeled 24-Hour High Deposition Rate for Dimethyl Mercury

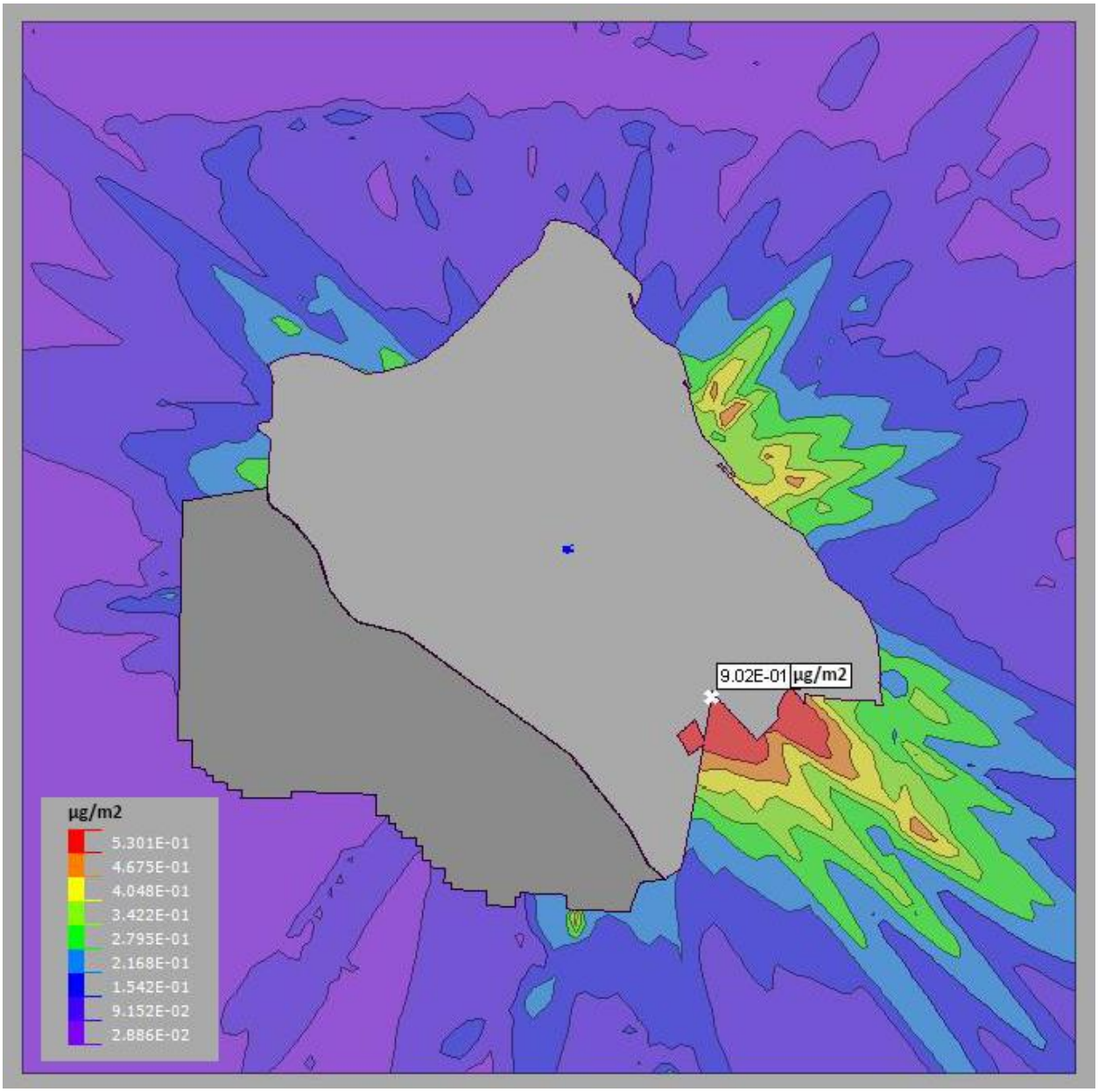
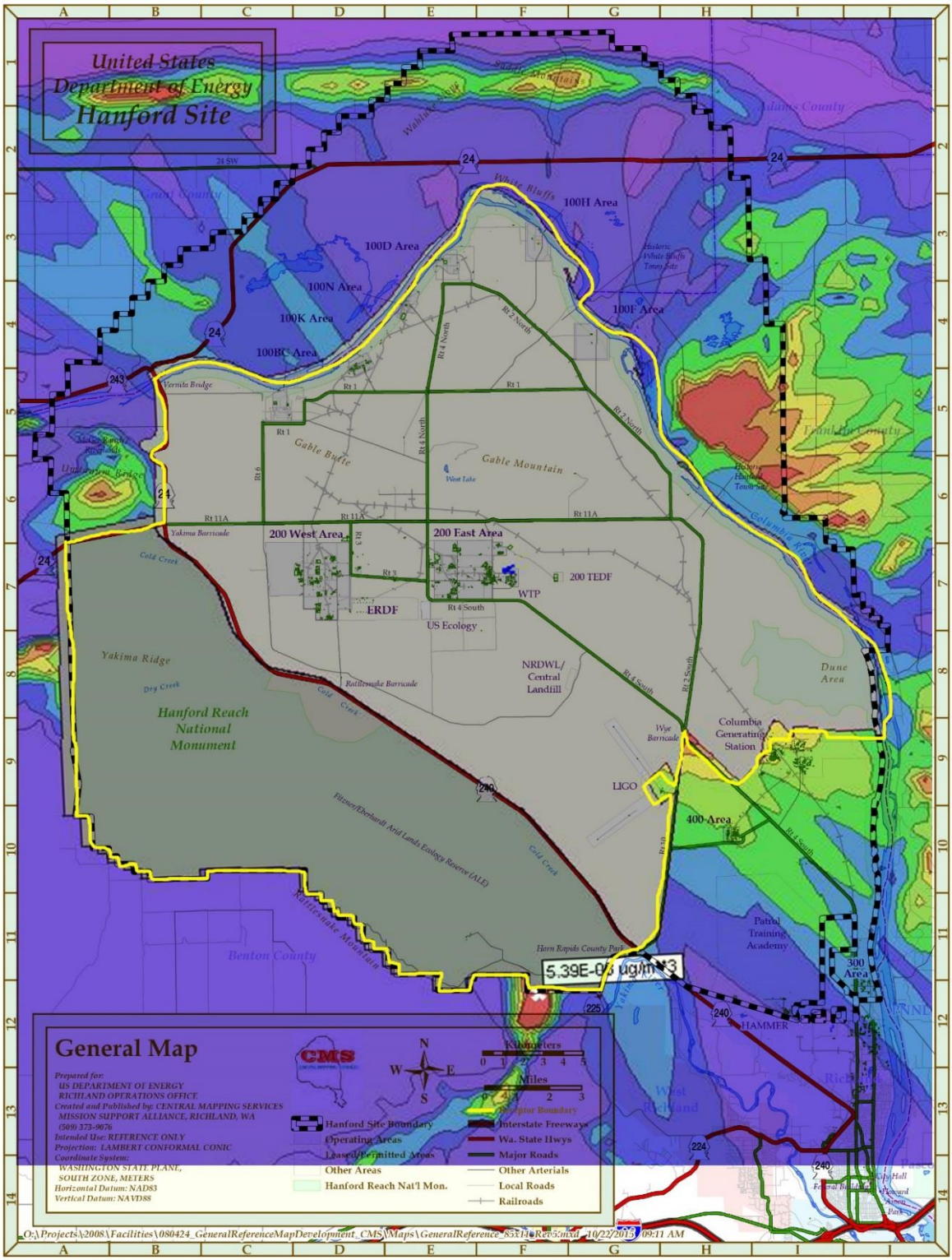


Figure 10. Hanford Site Map with location of Modeled 24-Hour High Concentration for Dimethyl Mercury



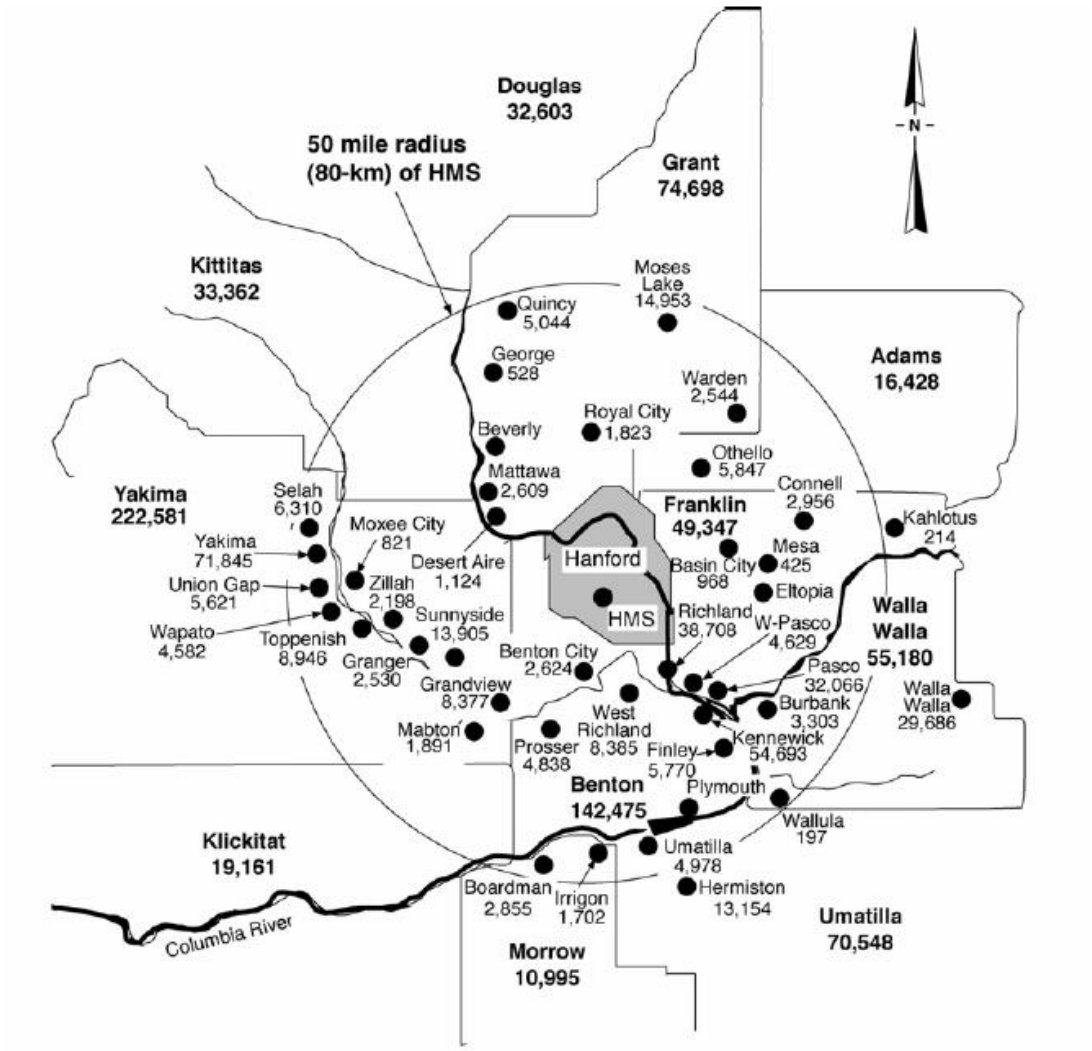
6.0 SENSITIVE POPULATION ANALYSIS

The Hanford Site has been restricted from public access since 1943. A report of the population and demographics of people living around the Hanford Site was conducted in 2004 based upon the 2000 Census (PNNL-14428, *Hanford Area 2000 Population*, 2004). The report analyzed the areas within 50 miles of selected sites at Hanford. For this analysis, the HMS was chosen as the reference point. Based on the 2000 census data, there are approximately 486,300 people living within 50 miles of the HMS. The resident population within 10 miles of HMS is estimated to be 23 people and 10,400 people are within 20 miles. Figure 11 shows the major towns and cities in the vicinity of the Hanford Site. Figure 12 shows the resident population within 50 miles of the HMS by direction and distance, each circle representing a 10-mile radius from HMS.

Figure 13 shows the land use and zoning for Benton County to the south and west of the Hanford Site. Figure 14 shows the land use and zoning for Franklin County and Figure 15 shows the land use and zoning for Grant County. Based upon the AERMOD modeling results provided in Sections 5.3.2 and 5.4.2 and Figure 13, the peak 24-hour air concentration occurs at a location zoned park district and the peak 24-hour deposition rate occurs on unclassified land.

The modeled high concentration along the south-central border of the Hanford Site boundary was chosen as the point of maximum impact for the 30-year mother-child exposure scenario and the 70-year resident exposure scenario (Figure 8). Both scenarios are conservative since no one lives at the peak concentration location and the concentration at the nearest resident is lower. The same assumption was made for deposition rates for both exposure scenarios. The project is only scheduled to last 40 years (assumed service life of modeled sources) and emissions were assumed to be at their maximum. Once emissions discontinue, pathways and uptake from inhalation and direct deposition no longer apply. The post-project risk for exposure through ingestion is due mainly to soil residual plant root uptake. However, the 70-year scenario calculates exposure based on maximum emissions for the full 70 years, including direct deposition for 70 years. This overestimates the ingestion pathway after 40 years, thus adding another level of conservatism to the 70-year scenario.

Figure 11. Map of the Hanford Site with Nearby Cities, Towns, and Counties



Note: If population not listed, less than 1,000.
HMS = Hanford Meteorological Station

Figure 12. Resident Populations within 50 Miles of the HMS in 10-mile Increments

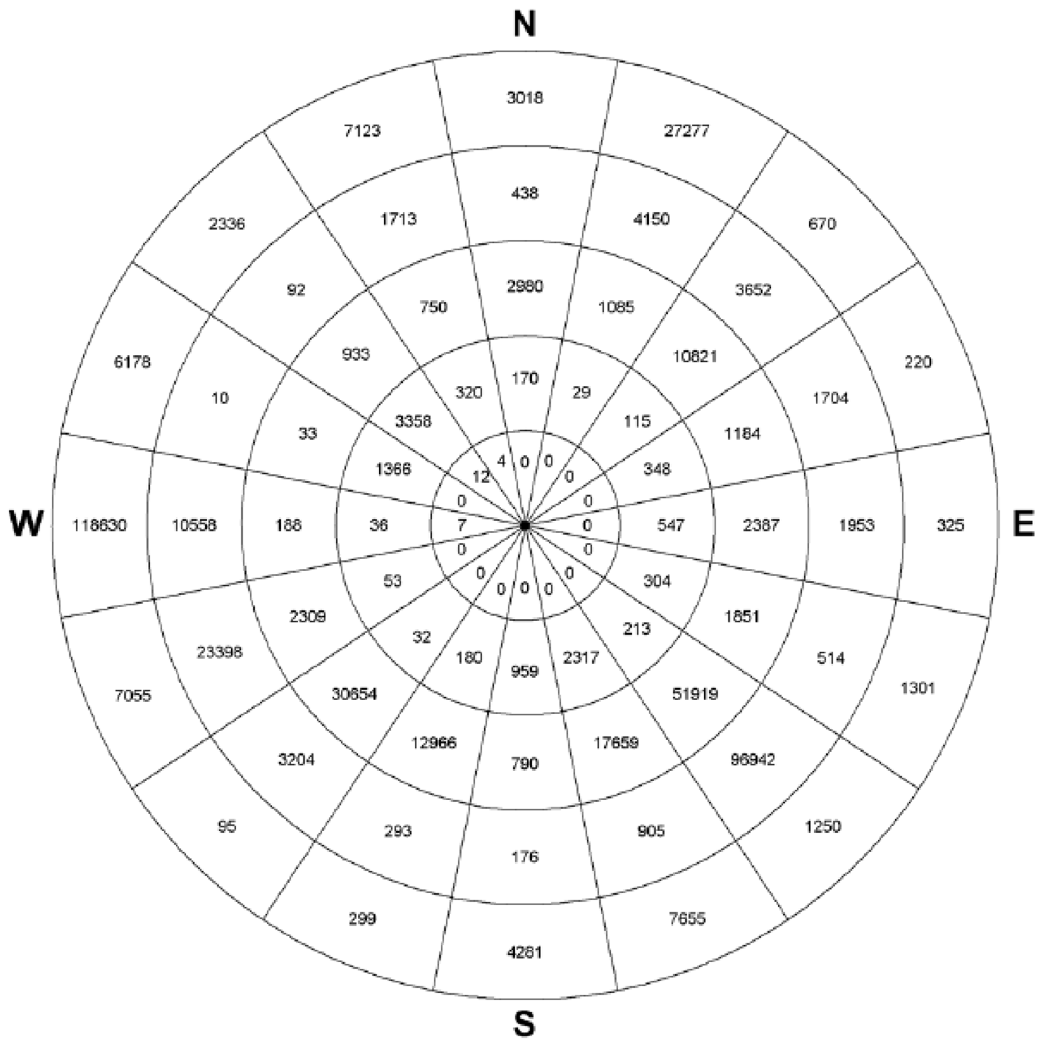


Figure 13. Benton County Land Use and Zoning Map

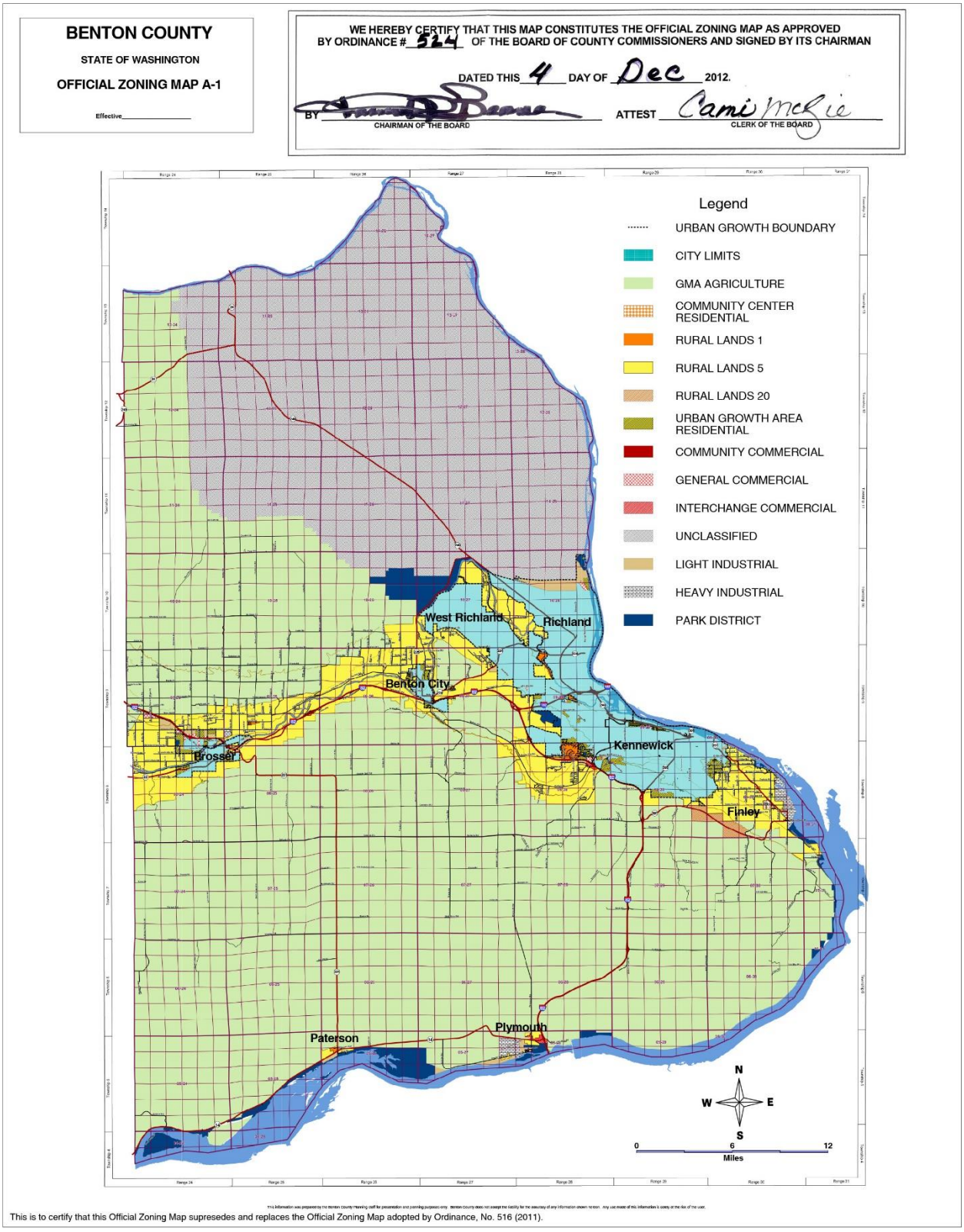


Figure 14. Franklin County Land Use and Zoning Map

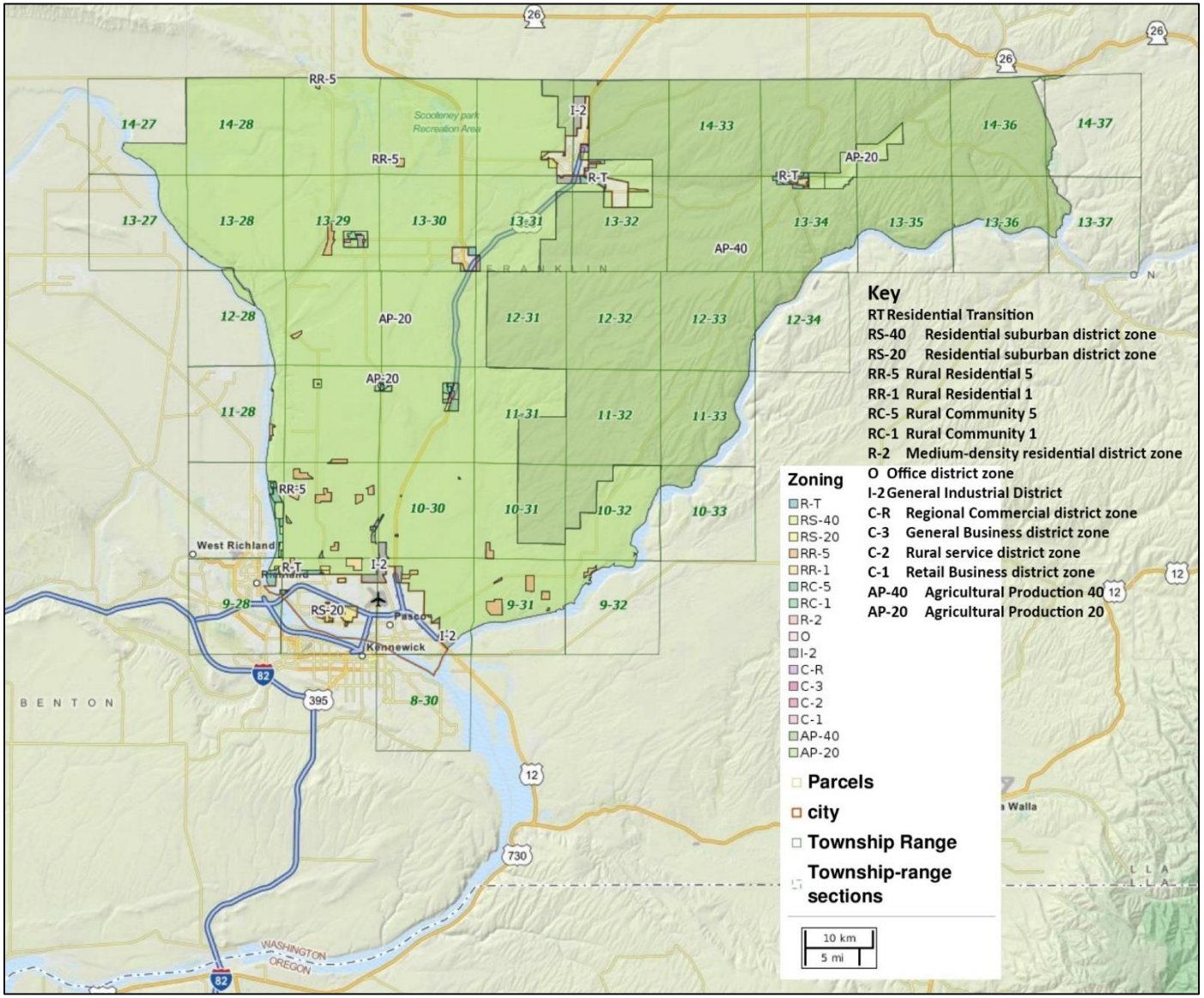
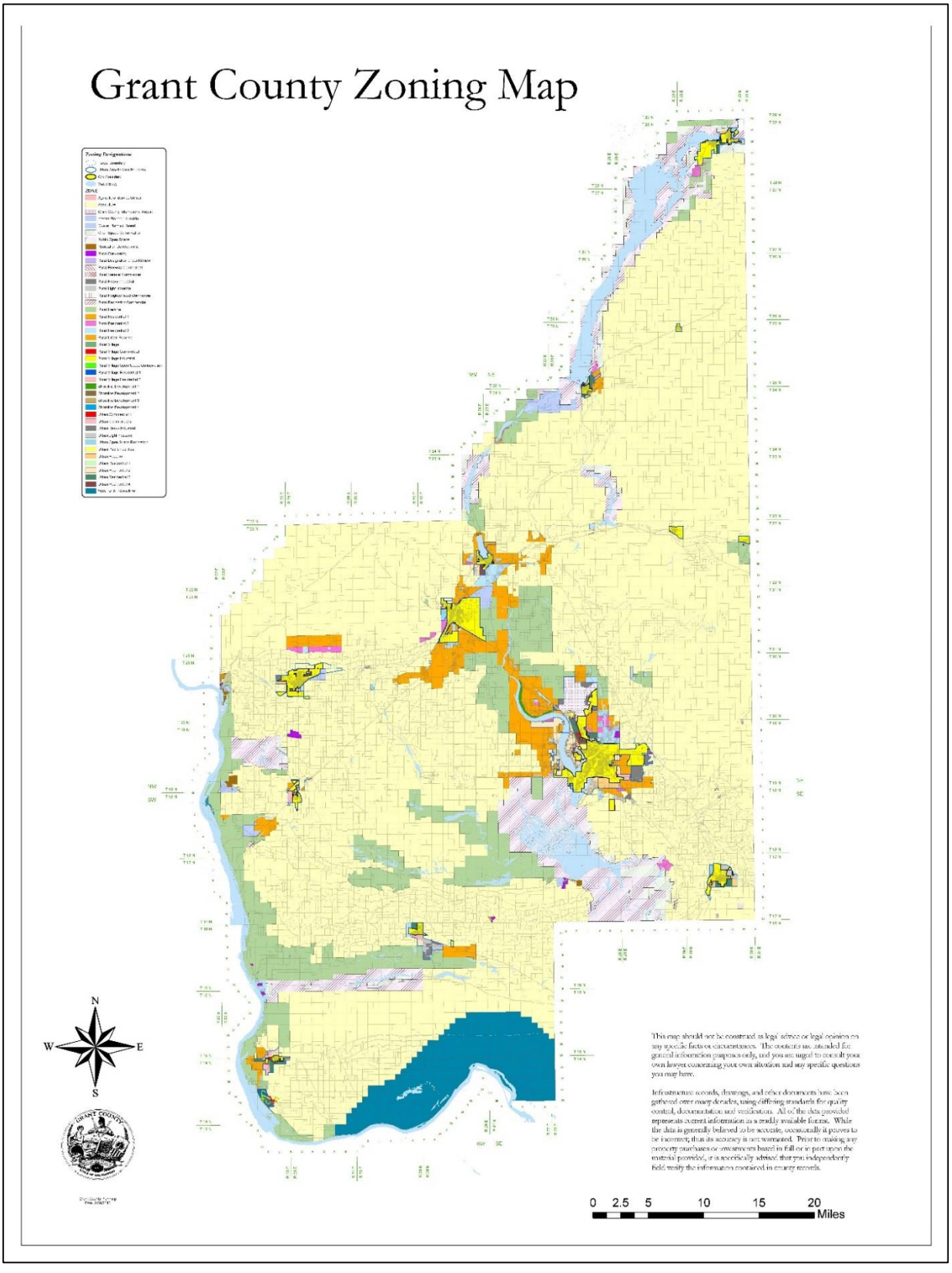


Figure 15. Grant County Land Use and Zoning Map



7.0 EXPOSURE ESTIMATION

As stated in the Health Impact Assessment Protocol approved by Ecology (Appendix A), two non-cancer pathways of exposure would be assessed in the DMM HIA: 1) inhalation, and 2) ingestion. Based on the concentrations modeled, the likelihood of DMM solubilizing in water is very low, and it was agreed that the water and fish ingestion pathways would not be assessed. In addition, based on conversations and agreement with Ecology, quantifying exposures via the dermal route, and via ingestion of meat, milk, eggs, and water, was very unlikely to yield significant concerns. Inhalation of air and ingestion of vegetables and soil are the only routes of exposure with significant potential to increase DMM body burden. The health impact assessment protocol followed was California EPA 2015, "The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (Hot Spots)."

Two exposure scenarios were analyzed:

1. The mother-child scenario with the mother and child living at the nearest offsite receptor with the highest ambient concentration and deposition. The mother-child scenario assesses health risk to a fetus through maternal exposure, and then subsequent exposure over 30 years. To assess the mother-child scenario it was assumed that the mother and child lived at that location for 30 years. The peak 24-hour concentration and deposition values were used to assess the 30-year exposure.

2. A person living at the site of the highest residential exposure. Based on the proximity of the nearest resident to the peak 24-hour concentration, the peak 24-hour concentration and deposition values were used to assess the 70-year exposure.

Sections 7.1 and 7.2 detail equations used to calculate the non-cancer inhalation and ingestion dose for each compound. The compound specific dose values are used to calculate the total health hazard index, as recommended by the California EPA. DMM calculations are detailed in Sections 7.1 and 7.2 as an example. Appendix D contains the Dimethyl Mercury Health Impacts Assessment Dose Spreadsheet which provides compound-specific calculations, including assumptions made for each compound.

7.1 ESTIMATION OF EXPOSURE THROUGH INHALATION

The inhalation exposure, Equation 1, was estimated using the California EPA guidance from February 2015. Equation 5.4.1.4 A from the EPA guidance is the recommended non-cancer inhalation dose equation.

$$Dose_{inh} = Modeled\ Air\ Concentration \quad (1)$$

The updated California EPA guidance recommends using the modeled air concentration as the suspected inhalation dose for non-cancer exposure. The DMM peak 24-hour modeled air concentration is 5.4E-03 µg/m^3. The modeled air concentration is then divided by the inhalation

reference exposure limit to calculate the inhalation hazard quotient for each compound. Each compound assessed in this HIA was modeled to obtain the peak 24-hour concentration. The peak 24-hour concentration is used in the dose spreadsheet provided in Appendix D, and summarized in Table 11.

7.2 ESTIMATION OF EXPOSURE THROUGH INGESTION

The human exposure through food ingestion depends upon the amount of pollutant that deposits on the plant while it is growing, as well as the amount of pollutant in the soil available for uptake by plant roots. The human exposure depends upon the consumption of those plants. To calculate the human exposure, it is first necessary to calculate the plant concentration.

The first step in the plant ingestion calculation is the estimation of the soil concentration. The California EPA guidance equation 5.3.2 A is:

$$C_s = \frac{Dep * X}{K_s * SD * Bd * T_t} \quad (2)$$

Where:

C_s	= Average soil concentration over the evaluation period (µg/kg)
Dep	= Deposition on the affected soil area per day (µg/m^2 * day)
X	= Integral function
K_s	= Soil elimination constant
SD	= Soil mixing depth (m)
BD	= Soil bulk density (kg/m^3)

For the purposes of this assessment, it was assumed that the most sensitive person was growing his/her garden at the modeled high deposition rate location. The California EPA recommended values for the SD is 0.15 m for an agricultural setting and the BD is 1,333 kg/m^3.

The integral function described in Equation 2 is detailed in Equation 3 below:

$$X = \frac{e^{-K_s * T_f} - e^{-K_s * T_o}}{K_s} + T_t \quad (3)$$

Where:

K_s	= Soil elimination constant
T_f	= End of evaluation period (day)
T_o	= Beginning of evaluation period (day)
T_t	= Total days of exposure [$T_f - T_o$] (days)

Using a 30-year exposure period, the number of days for the total exposure is 10,950, assuming that the exposure began on day zero. Using a 70-year exposure period the number of days for

the total exposure is 25,550, assuming that the exposure began on day zero. The soil elimination constant is given by equation 5.3.2 D in the California EPA document as:

$$K_s = \frac{0.693}{t_{1/2}} \quad (4)$$

Where:

0.693 = Natural log of 2
$t_{1/2}$ = Chemical specific soil half-life (days)

DMM does not have a calculated chemical specific half-life, therefore data for mercury and inorganic mercury compounds was assumed. Table 5.2b in the California EPA guidance manual states the mercury and inorganic mercury compound soil specific half-life as 1E+08 days. The soil elimination constant then becomes:

$$K_s = \frac{0.693}{1E{+}08\ days} \quad (5)$$

The value of K_s is therefore 6.9E-09 /days. The integral function for the 30-year exposure then becomes:

$$X = \frac{e^{-6.9\text{E}-09/day * 10{,}950\ days} - e^{-6.9\text{E}-09/day * 0\ days}}{1E{+}08\ days} + 10{,}950\ days \quad (6)$$

The integral function is 0.42 for the 30-year exposure and 2.3 for the 70-year exposure. To calculate the soil concentration using Equation (3), the 30-year exposure calculation is:

$$C_s = \frac{9.0E{-}01\ \mu g/m^2 * day * 0.42}{6.9E{-}09\ /day * 0.15\ m * 1{,}333\ kg/m^3 * 10{,}950\ days} \quad (7)$$

The 30-year exposure soil concentration of DMM is 2.5E+01 µg/kg assuming that the peak 24-hour deposition rate occurred over all 30 years of the analysis period. The 70-year exposure soil concentration of DMM is 5.8E+01 µg/kg assuming that the peak 24-hour deposition rate occurred over all 70 years of the analysis period.

The plant concentration is calculated from the soil concentration. The two pathways for DMM to enter the plant are direct deposition and through root uptake.

California EPA Equation 5.3.4.1 C was used to calculate the root uptake:

$$C_{uptake} = C_s * UF_2 \quad (8)$$

Where:

C_s = Average soil concentration (µg/kg)
UF_2 = Uptake factor based upon soil concentration

The highest root uptake factor for inorganic mercury was for leafy vegetables at 9.0E-02. For other organic compounds assessed in this HIA, the California EPA guidance lists an equation for calculating UF_2 for organic compounds. The calculation is detailed for each compound in the dose spreadsheet (Appendix D). The 30-year exposure calculation is:

$$C_{uptake} = 2.5\text{E}+01\ \mu g/kg * 9.0E-02 \quad (9)$$

Using this equation, the calculated 30-year exposure root uptake concentration is 2.2E+00 µg/kg, and the calculated 70-year exposure root uptake concentration is 5.2E+00 µg/kg. Next, the deposition concentration of the plant is needed to calculate the total burden of DMM in the plant.

The equation for the direct deposition on plants from the California EPA guidance is:

$$C_{dep} = \frac{Dep*IF}{k*Y} * (1 - e^{-kT}) \quad (10)$$

Where:

IF	= Interception fraction (unitless)
K	= Weathering constant ($days^{-1}$)
Y	= Yield (kg/m^2)
T	= Growth period (days)

The California EPA guidance recommended values for the interception fraction for leafy crops is 0.2, the weathering constant is 0.1 $days^{-1}$, and the growth period is 45 days. The 30-year exposure calculation is the following:

$$C_{dep} = \frac{9.0E-01\ \mu g/m^2 * day * 0.2}{0.1\ /day * 2\ kg/m^2} * (1 - e^{-0.1\ day * 45\ days}) \quad (11)$$

The 30-year exposure plant concentration due to deposition is then 8.9E-01 µg/kg, the total plant concentration is 3.1E+00 µg/kg. The 70-year exposure plant concentration due to deposition is then 8.9E-01 µg/kg, the total plant concentration is 6.1E+00 µg/kg.

To calculate the dose from ingestion of plants, equation 5.4.3.2.3 in the California EPA guidance was used:

$$Dose(food) = \frac{C_f * IP * GRAF * L * EF * ED * 10^{-6}}{AT} \quad (12)$$

Where:

C_f	= Concentration in plant (µg/kg)
IP	= Consumption of produce (g/kg*day)
GRAF	= Gastrointestinal relative absorption factor
L	= Fraction of produce homegrown

EF = Exposure frequency (days/year)
ED = Exposure duration (years)
10^{-6} = conversion factor (µg/kg to mg/g)
AT = Averaging time for exposure (days)

The 30-year exposure plant concentration is 3.1E+00 µg/kg. The 70-year exposure plant concentration is 6.1E+00 µg/kg. The California EPA recommended high end value for leafy produce is 10.8 g/kg body weight per day. A gastrointestinal absorption factor of one (i.e., assumes all DMM is absorbed into the body) was used. A factor of one was used for the fraction of homegrown produce. The exposure frequency was 350 days per year and the exposure duration was 30 years and 70 years. The averaging time for 30 years was 10,950 days and for 70 years it was 25,550 days.

The 30-year estimated plant ingestion dose is 3.2E-05 mg/kg body weight per day. The 70-year estimated plant ingestion dose is 6.3E-05 mg/kg body weight per day.

7.3 ESTIMATION OF TOTAL EXPOSURE

Calculated 30-year and 70-year inhalation and ingestion doses are divided by compound-specific exposure limits (Table 11 and Appendix D) to generate compound inhalation and ingestion dose hazard quotients. These hazard quotients are summed to generate a compound total dose hazard quotient. Total individual constituent dose hazard quotients are summed to generate the total neurotoxicity hazard index for this HIA.

Table 11. Neurotoxin Reference Exposure Limits and Model Output

CAS #	Compound	Modeled Air Concentration and Inhalation Dose ($\mu g/m^3$)	Inhalation Reference Concentration ($\mu g/m^3$)	Modeled Deposition Rate ($\mu g/m^2$)	30-Year Plant Ingestion Dose (mg/kg/day)	70-Year Plant Ingestion Dose (mg/kg/day)	Oral Reference Dose (mg/kg/day)
7440-38-2	Arsenic and Inorganic Arsenic Compounds	6.6E-07	1.5E-02	1.1E-03[a]	1.5E-08	1.9E-08	3.5E-06
71-43-2	Benzene	7.1E-03	3.0E+00	9.2E-04	9.5E-09	9.5E-09	4.0E-03
7440-43-9	Cadmium and Compounds	3.3E-07	2.0E-02	—	—	—	5.0E-04
593-74-8	Dimethyl Mercury	5.4E-03	1.4E-01	9.0E-01	3.2E-05	6.3E-05	1.0E-04
76-44-8	Heptachlor	1.7E-05	5.0E+02	1.1E-04	9.1E-10	9.2E-10	5E-04
118-74-1	Hexachlorobenzene	3.8E-06	3.00E+00	2.5E-05	1.6E-09	3.3E-09	8E-04
7439-97-6	Mercury, Elemental	8.6E-05	3.0E-02	1.9E-02	3.1E-07	4.5E-07	1.6E-04
10102-44-0	Nitrogen dioxide	2.4E-01	None	—	—	—	none
127-18-4	Perchloroethylene	7.1E-03	3.5E+01	3.6E-03	5.6E-08	5.6E-08	6.0E-03
1336-36-3	Polychlorinated Biphenyls (PCBs)	8.9E-05	1.3E+00	—	—	—	3.3E-04
79-01-6	Trichloroethylene	7.1E-03	2.0E+00	1.2E-03	2.0E-08	2.1E-08	5.0E-04
75-01-4	Vinyl Chloride	1.4E-01	1.0E+02	—	—	—	3.0E-03

Note 1: Compounds marked with a "— ", were not modeled for deposition rate, therefore plant ingestion dose could not be calculated. These compounds were not included in the calculation of the Hazard Index, as explained in Section 4.2.
Note 2: Inhalation and Oral Reference values obtained from: 1) Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values (May 13, 2015) http://www.arb.ca.gov/toxics/healthval/healthval.htm (AB 2588 Air Toxics "Hot Spots" REL), 2) http://oehha.ca.gov/air/allrels html (Provides Hazard Index Target Organs), 3) USEPA Integrated Risk Information System (IRIS): Reference Dose for Chronic Oral Exposure (RfD), Reference Concentration for Chronic Inhalation Exposure (RfC)
[a]Deposition parameterization values could not be located for arsenic, therefore the California EPA recommended deposition rate was used in the dose calculation (see Appendix D).

7.4 COMPARISON OF ESTIMATED EXPOSURE TO RISK

Hazard quotients were calculated for the two exposure scenarios. A hazard quotient is the ratio of the potential exposure of a person to a substance compared to the exposure level at which health effects are not expected.

$$HQ = \frac{Total\ Exposure\ Dose\ (inhalation\ or\ ingestion)}{Corresponding\ Chronic\ Reference\ Level}$$

The hazard quotient was calculated for each compound, as detailed in Appendix D. The 30-year and the 70-year exposure scenarios are below the threshold value of 1.0 indicating that the toxicological effects from DMM and the neurotoxic compound emissions from the Hanford Site are acceptable (Table 12).

Table 12. Neurotoxicity Hazard Quotients and Hazard Index

Compound	Hazard Quotient			
	30-Year Total		70-Year Total	
	Inhalation	Ingestion	Inhalation	Ingestion
Dimethyl Mercury	3.6E-01		6.7E-01	
	3.9E-02	3.2E-01	3.9E-02	6.3E-01
Arsenic and Inorganic Compounds	9.4E-05		1.1E-04	
	4.4E-05	5.0E-05	4.4E-05	6.4E-05
Benzene	2.4E-03		2.4E-03	
	2.4E-03	2.4E-03	2.4E-03	2.4E-03
Heptachlor	1.9E-06		1.9E-06	
	3.4E-08	1.8E-06	3.4E-08	1.8E-06
Hexachlorobenzene	3.2E-06		5.4E-06	
	1.3E-06	2.0E-06	1.3E-06	4.1E-06
Mercury, Elemental	2.2E-03		3.1E-03	
	2.9E-04	1.9E-03	2.9E-04	2.8E-03
Perchloroethylene	1.9E-04		1.9E-04	
	1.8E-04	9.3E-06	1.8E-04	9.3E-06
Trichloroethylene	5.3E-05		5.3E-05	
	1.2E-05	4.1E-05	1.2E-05	4.1E-05
Hazard Index	3.7E-01		6.7E-01	

8.0 ASSUMPTIONS

Assumptions were made throughout the assessment process. Assumptions are necessary for many reasons, including but not limited to, lack of knowledge, lack of scientific data, uncertainties, and/or conservative decisions. The assumptions made for this HIA are detailed throughout this document, and are summarized below for convenient reference.

- Modeled Source Emissions (Section 5.0)
  - AN Tank Farm, AP Tank Farm, AW Tank Farm, AY Tank Farm, AX Tank Farm, A Tank Farm, S Tank Farm, SY Tank Farm, and SX Tank Farm: A conservative factor of 100 was applied to the emission rate of one tank in each tank farm. The remaining tanks in each tank farm were assumed at the TWINS reported single tank emission rate. Single tank emission rates were summed to total a point source tank farm emission rate.
  - Drying Out Exhausters 1, 2, 3, and 4: Assumed at the TWINS reported single tank emission rate.
  - Core Sampler: Assumed at the TWINS reported single tank emission rate.
  - LAWPS: Assumed at the TWINS reported single tank emission rate.
  - Evaporator: Assumed at the TWINS reported single tank emission rate.
  - Effluent Treatment Facility: Values obtained from DE07NWP-003, Revision 1. Assumed at reported emission rate.
  - EMF: Assumed at the summed emission rate of WTP Pretreatment Stack PT-S3 and Pretreatment Stack PT-S4.
  - WTP: Assumed all TAP values from 2003 emissions estimates, as obtained in the WTP permit, except DMM assumed at reported elemental mercury emission rate from the 2006 integrated emissions report.
- TAP Emission Rates vs. WAC 173-460-150 (Table 6)
  - All point source emission rates for each TAP were summed to obtain a single Hanford Site TAP emission rate. These rates were compared to the levels listed in WAC 173-460-150. TAPs exceeding the SQER level were evaluated for inclusion in this HIA.
- Air Dispersion Modeling (Section 5.3)
  - Assumed a conservative factor of 100 for DMM on each point source emission rate. This factor is in addition to the initial tank farm factor of 100, as explained Section 5.1.
  - Only offsite receptors were modeled for this analysis, as shown in Figure 1.

  - All emission sources were modeled simultaneously, assuming waste disturbing activities were occurring in one tank in each tank farm.

  - All sources were assumed to be operating for the entire year to ensure the worst case situation would be modeled for 24-hour concentration.

  - Only DMM was modeled for the full 5 years in order to determine the 24-hour high concentration over a 5-year period. To determine the compounding effects of other neurotoxins with estimated emissions exceeding the SQER (Section 4.2), the other neurotoxins were modeled on the peak 24-hour DMM day.

- Elemental mercury (Section 5.1.2)
  - The WTP elemental mercury emission rates were used for DMM air modeling because no DMM emission rates were available. In order to avoid duplication of this conservative assumption, modeling for elemental mercury as a compounding neurotoxin excluded emissions from the WTP.

- Exposure Pathways (Section 7.0)
  - Deposition on soil and plants and ingestion of leafy vegetables were considered the likely oral exposure pathway for this assessment.

  - Based on prior conversations with Ecology (Appendix A protocol approval), quantifying exposures via the dermal route, and via ingestion of meat, milk, eggs, and water, was very unlikely to yield significant concerns. Based on the concentrations modeled, the likelihood of DMM solubilizing in water is very low, and it was determined that the water and fish ingestion pathways would not be assessed. The modeled high concentrations are just outside the Hanford Site boundary, where hunting and livestock are uncommon. The Columbia and Yakima Rivers have high flow rates, which quickly dilute any of the other neurotoxins that could be water soluble. Although trophic transfer from plants to animals to humans is a potential exposure scenario to consider, the likelihood of animals being ingested just outside the Hanford Site boundary is minimal.

- California Hot Spots Guidelines (Section 7.1)
  - The California Hot Spots Guidelines (California EPA 2015) were used to determine appropriate calculations, compounds for inclusion, and derivation of a final hazard index. Several assumptions were made for each individual TAP, and are referenced in the dose spreadsheet provided in Appendix D.

- Receptor Mapping (Section 2.3)
  - The WTP contributed over 95% of the DMM highest concentration receptor location. Receptors of concern (e.g., school, water body) within the region were distanced from the center of the WTP for this HIA.

9.0 UNCERTAINTY ANALYSIS

Assumptions based on lack of knowledge or available data can cause uncertainty when estimating human health impacts. Uncertainty can be found in most aspects of a project, including emission rates, air dispersion modeling, estimates of resulting environmental concentrations, exposure modeling to estimate received doses, and assessment of adverse health impacts of the project. Due to the lack of toxicity data concerning DMM, there is a large uncertainty in the impacts resulting from exposure to DMM. Uncertainty can overestimate or underestimate the health risk. The following discussions on uncertainty pertain to DMM, but the general concepts can also be applied to the compounding neurotoxins assessed in this HIA.

9.1 TOXICITY UNCERTAINTY

Very few instances of DMM exposure have been documented. The documented instances have been fatal, therefore a dose response relationship has not been developed. One study showed that DMM is converted to MeHg (Ostland 1969, "Studies on the Metabolism of Methyl Mercury in Mice"). It was therefore concluded that the RELs for MeHg would be the best assumed DMM RELs. The uncertainty of using MeHg RELs instead of DMM RELs is difficult to quantify due to a lack of data.

The MeHg REL developed by the NRC in 2000 listed two main categories of uncertainty: 1) biological variability in dose estimation, and 2) data insufficiencies. The NRC applied a factor of 2-3 to account for biological variability. They did not come up with a number for data insufficiencies, but concluded that the overall uncertainty factor should be no less than 10.

9.2 EXPOSURE UNCERTAINTY

It is difficult to assess the length of time that people will be exposed to DMM emissions. The selected exposure points coincide with the highest air concentration and highest deposition rate as determined from AERMOD, developing the most conservative scenario possible and minimizing concerns with exposure length uncertainty. In addition, it was assumed that someone lived at that exposure point for their entire lifetime, providing additional conservatism.

The assumption that all sources would be operating simultaneously non-stop and emitting at an inflated conservative assumed emission rate would overestimate the exposure. In addition, only ten tanks have actually been found to have DMM, and the assessment assumed all tanks were emitting DMM.

The background level of DMM is also very uncertain due to its low atmospheric concentration and the limited number of measurements made.

9.3 EMISSIONS UNCERTAINTY

The tank emission rates are based on concentrations measured in the headspace of the tank. The low concentrations of DMM in the headspace are near the analytical detection limits, so the uncertainty in the measurements leads to uncertainty in the emissions. However, the highest level detected in any tank was used for all tanks representing the Hanford Site tank farm emissions. Therefore, the assumptions in these emission estimates represent a worst case situation. In addition, one tank in each tank farm was modeled to be undergoing some type of waste disturbing activity for an entire year, with a highly exaggerated factor of 100. Thus, the uncertainty of emissions likely overestimates the project risk.

9.4 AIR DISPERSION MODELING UNCERTAINTY

The transport and dispersion of pollutants in the atmosphere is complex. Models developed make many assumptions to solve the dispersion equations. Differences in the wind field over the modeling domain can have large impacts on the modeled concentration. Meteorological data can change over time, while the model uses the last documented 5 years of data to model for future scenarios. However, AERMOD is a regulatory model and is designed to be conservative in its estimate of concentrations. Most likely, the modeling overestimates the project risk.

Other AERMOD inputs may change over time, which could change the modeled dispersed concentration. This includes, but is not limited to, emission rates and the Hanford Site boundary. As the Hanford Site completes various environmental cleanup projects, the site boundaries may change and the area may shrink, allowing public access in certain currently restricted areas. This document does not assess impact to the public within the Hanford Site boundary.

9.5 DERIVATION OF HAZARD INDEX

Many California EPA Hot Spots (California EPA 2015) dose calculations required inputs particular to the specific compound. Mercury data was used as an input for many of the DMM calculations. In order to maintain conservatism, the worst-case value was always chosen to calculate potential dose. Mercury data for the 70-year exposure scenario overestimated the dose because the ingestion dose calculation assumes exposure falls to zero at 40 years, while the calculation considered dose for 70 years. This results in no DMM soil loss, and thus an overestimation of the 70-year exposure scenario.

10.0 CONCLUSIONS

A health impact assessment was completed to determine whether Hanford Site DMM emissions, including compounding effects from other neurotoxic pollutants, could have a potential adverse health impact on the public. A number of conservative assumptions were made to estimate the health risk.

- The emissions from the tank farm sources and exhausters were assumed to be at the highest emission rates from all tanks in tank farms. Only 10 of the 177 tanks have actually had detectable concentrations of DMM. The modeled tank farms sources were assumed to have the peak emission rate for the entire year.

- Modeled WTP sources were assumed to have DMM emissions equal to the current air permit limits for elemental mercury.

- Two exposure scenarios were analyzed.

    - The mother-child scenario with the mother and child living at the nearest offsite receptor with the highest ambient concentration and deposition. The mother-child scenario assesses health risk to a fetus through maternal exposure, and then subsequent exposure over 30 years. To assess the mother-child scenario, it was assumed that the mother and child lived at that location for 30 years. The peak 24-hour concentration and deposition values were used to assess the 30-year exposure.

    - A person living at the site of the highest residential exposure. Based on the proximity of the nearest resident to the peak 24-hour concentration, the peak 24-hour concentration and deposition values were used to assess the 70-year exposure.

- The ingestion rates were assumed to be the maximum according to the California EPA guidance.

- The maximum 24-hour concentration and deposition rates were assumed to be occurring for the entire 30-year and 70-year analyses.

The conservative assumptions made in this HIA resulted in an overestimation of the potential health impacts from DMM and other neurotoxin emissions. The calculated hazard index for a mother-child 30-year exposure is 3.7E-01, a level below the threshold value of 1.0. The calculated hazard index for a 70-year resident exposure is 6.7E-01, a level also below the threshold value of 1.0. Both of these hazard indices indicate that DMM and other neurotoxin emissions from the Hanford Site should not pose any threat to the public.

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Wesley, M.L., Doskey, P.V., and Shannon, J.D., 2002, "Deposition Parameterizations for the Industrial Source Complex (ISC3) Model Appendix B," U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Washington D.C.

WAC 173-460-060(2), "Control Technology Requirements," *Washington Administrative Code*, as amended.

WAC 173-460-080, "First Tier Review," *Washington Administrative Code*, as amended.

WAC 173-460-090, "Second Tier Review," *Washington Administrative Code*, as amended.

WAC 173-460-150, "Table of Acceptable Source Impact Level, Small Quantity Emission Rate and De Minimis Emission Values," *Washington Administrative Code*, as amended.

APPENDIX A

HEALTH IMPACT ASSESSMENT PROTOCOL

Health Impact Assessment Protocol

"Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions"
(RPP-RPT-58709)

The following information is provided to Ecology to satisfy the requirements of WAC 173-460-090(3). The outlined protocol for preparation of the "bounding" Hanford Site dimethyl mercury (DMM) health impacts assessment (HIA) document is reflective of and consistent with technical discussions with Ecology staff on February 11, March 30 and August 6, 2015; as well as Ecology's HIA guidance manual. Once approved by Ecology, the HIA document will be used to satisfy second tier review requirements for future Hanford Site notice of construction applications that trigger such requirements for dimethyl mercury and which are bounded by the activities/scope described in the HIA document.

In general, the "bounding" DMM HIA will be prepared consistent with the Ecology- approved protocol for previous Hanford Site project-specific dimethyl mercury HIAs that were reviewed and approved by Ecology. Adjustments to the HIA development process were made to reflect the "bounding" nature of this effort.

References:
1) RPP-ENV-48231, "Second Tier Review Petition for the Operation of the 241-SY, 241-AP, and 241-AY/AZ Tank Farm Ventilation System Upgrades", January 2011.
2) Ecology review document, "Technical Support Document for Second Tier Review: 241-SY, 241-AP, and 241-AY/AZ Tank Farm Ventilation System Upgrades at the Hanford Site, Benton County, Washington", July 2011
3) TOC-ENV-NOC-0008, "Second Tier Review Petition for the Operation of the Core Sampler in High Purge Gas Mode", May 2014

The DMM HIA will include the following information elements:

1. Project description
   a. Map of sources and surrounding areas
   b. Location of emission points
   c. Scope of covered activities, including bounding assumptions for emissions estimates
2. Hazard identification
   a. List and description of toxic air pollutants (TAPs) included in HIA
   b. Environmental fate/transport characteristics for TAPs
3. Modeling methods and results
   a. AERMOD parameters and details
   b. Meteorological data information
   c. Averaging periods used for modeling
   d. Receptor grid spacing
   e. Modeling results
4. Identification of potentially exposed populations and susceptible subpopulations
   a. Location of maximally exposed individual(s)

5. Exposure assessment
   a. Identification of TAP exposure pathways
   b. Background concentration estimates
   c. Total daily intake attributable to modeled source(s)
6. Toxicity
   a. Description of toxic effects and exposure levels from scientific references
   b. Quantitative chronic toxicity values
7. Risk/hazard assessment
   a. Qualitative and quantitative discussion of risks and acceptability of those risks
   b. Discussion of potential impact of exposure to human health
   c. Discussion of modeling uncertainties

Additional aspects and details of this "bounding" HIA (versus a more traditional project/source-specific HIA document) that are worth highlighting include:

- Estimated TAP emissions do not correlate directly to actual individual Hanford Site source or activity. Assumed emissions scenario is a hypothetical compilation of 20+ existing and planned sources at both Tank Farms and WTP operating simultaneously at either maximum permitted emission rates or assumed rates that are 100X actual sampling data to create a "bounding" worst case.
- Other TAPs with similar health effects to DMM (neurotoxicity) were included in the HIA to assess compounding health impact if estimated emissions from same compilation of Tanks Farms and WTP sources exceeded corresponding small quantity emission rate (SQER).
- California Air Toxics Hot Spots Program Guidance Manual used to develop and calculate ingestion pathway hazard quotients for each TAP.
- 24-hr modeling runs were performed for each compounding TAP included in the HIA to maintain consistency with the DMM 24-hr averaging period identified in WAC 173-460-150.

****

February 11, 2015 Richland meeting participants (video-teleconference w/ Lacey HQ staff):
Ecology: Clint Bowman, Phil Gent, Rich Hibbard, Jeff Johnston, Matt Kadlec, Dan McDonald, Stephanie Schleif
DOE-ORP/WRPS/BNI: Tom Beam, Lucinda Borneman, Dennis Bowser, Dave Blumenkranz, Bob Haggard, Brian Rumburg

March 30, 2015 Richland meeting participants (video-teleconference w/ Lacey HQ staff):
Ecology: Clint Bowman, Ranil Dhammapala, Phil Gent, Rich Hibbard, Matt Kadlec
DOE-ORP/WRPS/BNI: Tom Beam, Dave Blumenkranz, Bob Haggard, Brian Rumburg,

August 6, 2015 Richland meeting participants (video-teleconference w/ Lacey HQ staff):
Ecology: Clint Bowman, Phil Gent, Rich Hibbard, Matt Kadlec
DOE-ORP/WRPS/BNI: Tom Beam, Lucinda Borneman, Dennis Bowser, Dave Blumenkranz, Bob Haggard, Brian Rumburg, Tanya Williams

APPENDIX B

TOXIC AIR POLLUTANT EMISSION RATES AND WAC 173-460 COMPARISON

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
100-41-4	Ethylbenzene	Year	1.93E-02	--	--	1.32E+03	7.68E+01	Yes	No
100-42-5	Styrene	24-hr	6.31E-03	--	1.20E+00	--	1.18E+02	No	No
100-44-7	Benzyl Chloride	Year	1.93E-04	--	--	1.32E+01	3.91E+00	Yes	No
10102-44-0	Nitrogen dioxide*	1-hr	9.14E-01	7.25E+00	--	--	1.03E+00	Yes	Yes
101-77-9	4,4-Methylenedianiline	year	7.38E-05	--	--	5.06E+00	4.16E-01	Yes	No
103-33-3	Azobenzene	year	7.38E-05	--	--	5.06E+00	6.20E+00	No	No
10595-95-6	n-Nitroso-n-methylethylamine	Year	2.65E-05	--	--	1.81E+00	3.05E-02	Yes	No
106-42-3	p-Xylene	24-hr	2.22E-02	--	4.24E+00	--	2.90E+01	No	No
106-44-5	p-Cresol (4-Methyl phenol)	24-hr	7.38E-05	--	1.41E-02	--	7.89E+01	No	No
106-46-7	1,4-Dichlorobenzene	Year	1.01E-03	--	--	6.89E+01	1.74E+01	Yes	No
106-88-7	1,2-Epoxybutane	24-hr	5.54E-04	--	1.05E-01	--	2.63E+00	No	No
106-89-8	Epichlorohydrin (1-chloro-2,3-epoxypropane)	year	9.84E-06	--	--	6.74E-01	8.35E+00	No	No
106-93-4	1,2-Dibromoethane	Year	7.91E-03	--	--	5.43E+02	2.71E+00	Yes	No
106-99-0	1,3-Butadiene	Year	2.72E-03	--	--	1.87E+02	1.13E+00	Yes	No
107-02-8	Acrolein	24-hr	4.60E-05	--	8.76E-03	--	7.89E-03	Yes	No
107-05-1	Allyl Chloride	Year	1.41E-04	--	--	9.66E+00	3.20E+01	No	No
107-06-2	1,2-Dichloroethane	Year	2.22E-02	--	--	1.52E+03	7.39E+00	Yes	No
107-13-1M	Acrylonitrile	Year	1.73E-04	--	--	1.19E+01	6.62E-01	Yes	No
107-21-1	Ethylene glycol	24-hr	9.84E-06	--	1.87E-03	--	5.26E+01	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
107-98-2	Propylene gylcol monomethyl ether	24-hr	7.38E-05	--	1.41E-02	--	9.20E+02	No	No
108-05-4	Vinyl acetate	24-hr	1.43E-05	--	2.72E-03	--	2.63E+01	No	No
108-10-1	Methyl Isobutyl Ketone	24-hr	3.78E-02	--	7.20E+00	--	3.94E+02	No	No
108-38-3M	m-Xylene	24-hr	1.29E-02	--	2.45E+00	--	2.90E+01	No	No
108-39-4	3-Methylphenol	24-hr	1.37E-04	--	2.60E-02	--	7.89E+01	No	No
108-88-3	Toluene	24-hr	5.58E-01	--	1.06E+02	--	6.57E+02	No	No
108-90-7	Chlorobenzene	24-hr	6.97E-03	--	1.33E+00	--	1.31E+02	No	No
108-95-2	Phenol	24-hr	1.12E-01	--	2.13E+01	--	2.63E+01	No	No
109-86-4	2-Methoxyethanol	24-hr	7.38E-05	--	1.41E-02	--	7.89E+00	No	No
110-54-3	n-Hexane	24-hr	7.05E-02	--	1.34E+01	--	9.20E+01	No	No
110-80-5	2-Ethoxyethanol	24-hr	7.38E-05	--	1.41E-02	--	9.20E+00	No	No
110-82-7	Cyclohexane	24-hr	2.16E-02	--	4.11E+00	--	7.89E+02	No	No
111-15-9	Ethylene glycol monoethyl ether acetate	24-hr	7.38E-05	--	1.41E-02	--	3.94E+01	No	No
111-44-4	Bis(2-chloroethyl) ether	year	7.38E-05	--	--	5.06E+00	2.71E-01	Yes	No
111-76-2	Ethylene glycol monoethyl ether acetate	24-hr	4.28E-03	--	8.15E-01	--	1.71E+03	No	No
1120-71-4	1,3-Propane sultone	year	7.38E-05	--	--	5.06E+00	2.78E-01	Yes	No
115-07-1	Propylene	24-hr	5.36E-02	--	1.02E+01	--	3.94E+02	No	No
117-81-7	Di(2-ethylhexyl)phthalate	Year	9.64E-05	--	--	6.61E+00	8.00E+00	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
118-74-1	Hexachlorobenzene*	year	8.88E-06	--	--	6.09E-01	3.76E-01	Yes	Yes
121-14-2	2,4-Dinitrotoluene	year	7.38E-05	--	--	5.06E+00	2.15E+00	Yes	No
121-44-8	Triethylamine	24-hr	2.45E-06	--	4.67E-04	--	2.63E+01	No	No
122-66-7	1,2-Diphenylhydrazine	year	7.38E-05	--	--	5.06E+00	7.68E-01	Yes	No
123-91-1	1,4-Dioxane	Year	9.75E-03	--	--	6.69E+02	2.49E+01	Yes	No
124-48-1	Chlorodibromomethane	year	9.84E-06	--	--	6.74E-01	7.10E+00	No	No
127-18-4	Perchloroethylene*	Year	2.36E-02	--	--	1.62E+03	3.24E+01	Yes	Yes
1310-73-2	Sodium Hydroxide	1-hr	1.11E-07	8.84E-07	--	--	1.75E-02	No	No
1314-62-1	Vanadium Pentoxide	1-hr	1.60E-03	1.27E-02	--	--	6.57E-02	No	No
133-06-2	Captan	year	7.38E-05	--	--	5.06E+00	2.92E+02	No	No
1336-36-3	Polychlorinated Biphenyls (PCBs)*	Year	2.78E-04	--	--	1.91E+01	3.36E-01	Yes	Yes
156-60-5	Trans-1,2-dichloroethene	24-hr	3.32E-06	--	6.33E-04	--	1.06E+02	No	No
1634-04-4	Methyl tert-butyl ether	year	1.79E-06	--	--	1.23E-01	7.39E+02	No	No
16984-48-8	Flouride	24-hr	1.16E-08	--	2.21E-06	--	1.71E+00	No	No
1746-01-6	2,3,7,8-Tetrachlorodibenzo(p)dioxin (TCDD)	year	4.61E-11	--	--	3.16E-06	5.05E-06	No	No
1836-75-5	Nitrofen	year	1.10E-11	--	--	7.57E-07	8.35E+00	No	No
18540-29-9	Chromium (hexavalent)	year	2.26E-09	--	--	1.55E-04	1.28E-03	No	No
189-55-9	Dibenzo[a,i]pyrene	year	1.94E-11	--	--	1.33E-06	1.74E-02	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
189-64-0	Dibenzo[a,h]pyrene	year	1.94E-11	--	--	1.33E-06	1.74E-02	No	No
191-30-0	Benzo[a,i]pyrene	year	1.94E-11	--	--	1.33E-06	1.74E-02	No	No
192-65-4	Dibenzo[a,e]pyrene	year	1.94E-11	--	--	1.33E-06	1.74E-01	No	No
193-39-5	Indeno(1,2,3-cd)pyrene	year	1.10E-11	--	--	7.57E-07	1.74E+00	No	No
19408-74-3	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin	year	7.67E-11	--	--	5.26E-06	5.05E-05	No	No
205-82-3	Benzo(j)fluoranthene	year	1.37E-11	--	--	9.42E-07	1.74E+00	No	No
205-99-2	Benzo(b)fluoranthene	year	1.10E-11	--	--	7.57E-07	1.74E+00	No	No
207-08-9	Benzo(k)fluoranthene	year	1.10E-11	--	--	7.57E-07	1.74E+00	No	No
218-01-9	Chrysene	year	3.47E-12	--	--	2.38E-07	1.74E+01	No	No
224-42-0	Dibenz[a,j]acridine	year	1.99E-11	--	--	1.36E-06	1.74E+00	No	No
226-36-8	Dibenz[a,h]acridine	year	1.99E-11	--	--	1.36E-06	1.74E+00	No	No
2385-85-5	Mirex	year	4.19E-04	--	--	2.87E+01	3.76E-02	Yes	No
25013-16-5	Butylated hydroxyanisole	Year	1.94E-05	--	--	1.33E+00	3.36E+03	No	No
309-00-2	Aldrin	year	2.96E-08	--	--	2.03E-03	3.91E-02	No	No
31508-00-6	2,3',4,4',5-Pentachlorobiphenyl (PBC 118)	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
319-84-6	Hexachlorocyclohexane (Lindane) Alpha BHC	year	9.86E-07	--	--	6.76E-02	2.49E-01	No	No
319-85-7	Hexachlorocyclohexane (Lindane) Beta BHC	year	3.67E-14	--	--	2.52E-09	4.47E-01	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
32598-13-3	3,3',4,4'-Tetrachlorobiphenyl (TCB)	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
3268-87-9	Octachlorodibenzo(p)dioxin	year	3.84E-10	--	--	2.63E-05	5.05E-02	No	No
32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
35822-46-9	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin	year	1.54E-10	--	--	1.06E-05	5.05E-04	No	No
3697-24-3	5-Methylchrysene	year	3.24E-12	--	--	2.22E-07	1.74E-01	No	No
38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl (PCB 157)	year	5.75E-15	--	--	3.94E-10	1.01E-02	No	No
39001-02-0	Octachlorodibenzofuran	year	3.07E-10	--	--	2.11E-05	5.05E-02	No	No
39227-28-6	1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin	year	7.67E-11	--	--	5.26E-06	5.05E-05	No	No
39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
40321-76-4	1,2,3,7,8-Pentachlorodibenzo(p)dioxin	year	7.67E-11	--	--	5.26E-06	5.05E-06	No	No
50-00-0	Formaldehyde	Year	5.28E-04	--	--	3.62E+01	3.20E+01	Yes	No
50-29-3	4,4-DDT	year	6.90E-08	--	--	4.73E-03	1.98E+00	No	No
50-32-8	Benzo(a)pyrene	year	1.40E-13	--	--	9.60E-09	1.74E-01	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
510-15-6	Chlorobenzilate	year	7.38E-05	--	--	5.06E+00	6.20E+00	No	No
51207-31-9	2,3,7,8-Tetrachlorodibenzofuran	year	3.84E-11	--	--	2.63E-06	5.05E-05	No	No
51-79-6	Ethyl Carbamate (urethane)	year	7.38E-05	--	--	5.06E+00	6.62E-01	Yes	No
52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
532-27-4	2-Chloroacetophenone	24-hr	7.38E-05	--	1.41E-02	--	3.94E-03	Yes	No
53-70-3	Dibenzo(a,h)anthracene	year	2.29E-14	--	--	1.57E-09	1.60E-01	No	No
540-73-8	1,2-Dimethylhydrazine	year	9.84E-06	--	--	6.74E-01	1.20E-03	Yes	No
542-75-6	1,3-Dichloropropene	year	9.84E-06	--	--	6.74E-01	1.20E+01	No	No
542-88-1	Dichloromethyl ether	year	9.84E-06	--	--	6.74E-01	1.48E-02	Yes	No
55-18-5	n-Nitrosodiethylamine	year	2.65E-05	--	--	1.81E+00	1.92E-02	Yes	No
55673-89-7	1,2,3,4,7,8,9-Heptachlorodibenzofuran	year	7.67E-11	--	--	5.26E-06	5.05E-04	No	No
56-23-5	Carbon Tetrachloride	Year	2.55E-02	--	--	1.75E+03	4.57E+00	Yes	No
56-49-5	3-Methylcholanthrene	year	3.89E-12	--	--	2.67E-07	3.05E-02	No	No
56-55-3	Benzo(a)anthracene	year	3.50E-12	--	--	2.40E-07	1.74E+00	No	No
57117-31-4	2,3,4,7,8-Pentachlorodibenzofuran	year	3.84E-11	--	--	2.63E-06	1.01E-05	No	No
57117-41-6	1,2,3,7,8-Pentachlorodibenzofuran	year	3.84E-11	--	--	2.63E-06	1.01E-04	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
57117-44-9	1,2,3,6,7,8-Hexachlorodibenzofuran	year	6.15E-11	--	--	4.22E-06	5.05E-05	No	No
57-14-7	1,1-Dimethylhydrazine	24-hr	1.94E-04	--	3.70E-02	--	6.57E-02	No	No
57465-28-8	3,3',4,4',5-Pentachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-05	No	No
57-55-6	Propylene Glycol	24-hr	3.07E-03	--	5.86E-01	--	3.75E+00	No	No
57653-85-7	1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin	year	7.67E-11	--	--	5.26E-06	5.05E-05	No	No
57-74-9	Chlordane	year	7.38E-05	--	--	5.06E+00	5.64E-01	Yes	No
584-84-9	2,4-Toluene diisocyante	24-hr	7.38E-05	--	1.41E-02	--	9.20E-03	Yes	No
58-89-9	gamma-BHC (Lindane)	year	1.18E-14	--	--	8.10E-10	6.20E-01	No	No
593-60-2	Bromoethene	24-hr	9.84E-06	--	1.87E-03	--	3.94E-01	No	No
593-74-8	DMM*	24-hr	5.62E-07	--	1.07E-04	--	1.00E-99	Yes	Yes
59-89-2	n-Nitrosomorpholine	Year	1.61E-03	--	--	1.10E+02	1.01E-01	Yes	No
60-11-7	Dimethyl aminoazobenzene	year	7.38E-05	--	--	5.06E+00	1.48E+07	No	No
602-87-9	5-Nitroacenaphthene	year	3.70E-12	--	--	2.54E-07	5.18E+00	No	No
60-35-5	Acetamide	Year	8.27E-05	--	--	5.67E+00	9.59E+00	No	No
60-35-5	Acetamide	year	3.41E-04	--	--	2.34E+01	9.59E+00	Yes	No
60-57-1	Dieldrin	year	6.24E-08	--	--	4.28E-03	4.16E-02	No	No
60851-34-5	2,3,4,6,7,8-Hexachlorodibenzofuran	year	6.93E-11	--	--	4.75E-06	5.05E-05	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
621-64-7	n-Nitrosodi-n-propylamine	Year	2.94E-04	--	--	2.02E+01	9.59E-02	Yes	No
624-83-9	Methyl Isocyanate	24-hr	3.96E-05	--	7.55E-03	--	1.31E-01	No	No
62-53-3	Aniline	year	7.38E-05	--	--	5.06E+00	1.20E+02	No	No
62-75-9	n-Nitrosodimethylamine	Year	3.67E-02	--	--	2.52E+03	4.16E-02	Yes	No
630-08-0	Carbon monoxide	1-hr	5.83E-01	4.63E+00	--	--	5.04E+01	No	No
630-20-6	1,1,1,2-Tetrachloroethane	year	1.57E-03	--	--	1.08E+02	2.59E+01	Yes	No
65510-44-3	2',3,4,4',5-Pentachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
67-56-1	Methyl Alcohol	24-hr	9.71E-01	--	1.85E+02	--	5.26E+02	No	No
67562-39-4	1,2,3,4,6,7,8-Heptachlorodibenzofuran	year	7.67E-11	--	--	5.26E-06	5.05E-04	No	No
67-63-0	Isopropyl Alcohol	1-hr	4.61E-02	3.66E-01	--	--	7.01E+00	No	No
67-66-3	Chloroform	Year	3.01E-02	--	--	2.06E+03	8.35E+00	Yes	No
67-72-1	Hexachloroethane	Year	2.44E-02	--	--	1.67E+03	1.74E+01	Yes	No
69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	1.01E-02	No	No
70362-50-4	3,4,4',5-Tetrachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	5.05E-02	No	No
70648-26-9	1,2,3,4,7,8-Hexachlorodibenzofuran	year	6.93E-11	--	--	4.75E-06	5.05E-05	No	No
71-43-2	Benzene*	Year	2.24E-02	--	--	1.53E+03	6.62E+00	Yes	Yes
71-55-6	1,1,1-Trichloroethane	24-hr	9.36E-04	--	1.78E-01	--	1.31E+02	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
72-54-8	4,4-DDD	year	2.16E-14	--	--	1.48E-09	2.78E+00	No	No
72-55-9	4,4-DDE	year	5.26E-09	--	--	3.61E-04	1.98E+00	No	No
72918-21-9	1,2,3,7,8,9-Hexachlorodibenzofuran	year	7.67E-11	--	--	5.26E-06	5.05E-05	No	No
7439-92-1	Lead and compounds (NOS)	Year	2.35E-06	--	--	1.61E-01	1.60E+01	No	No
7439-96-5	Manganese & Compounds	24-hr	4.47E-07	--	8.52E-05	--	5.26E-03	No	No
7439-97-6	Mercury, Elemental*	24-hr	3.95E-04	--	7.52E-02	--	1.18E-02	Yes	Yes
7440-38-2	Arsenic & Inorganic Arsenic Compounds*	Year	2.70E-06	--	--	1.85E-01	5.81E-02	Yes	Yes
7440-41-7	Beryllium & Compounds (NOS)	Year	4.48E-05	--	--	3.08E+00	8.00E-02	Yes	No
7440-43-9	Cadmium & Compounds*	Year	1.18E-06	--	--	8.09E-02	4.57E-02	Yes	Yes
7440-47-3	Chromium Hexavalent: Soluble, except Chromic Trioxide	Year	1.37E-03	--	--	9.40E+01	1.28E-03	Yes	No
7440-48-4	Cobalt	24-hr	8.95E-04	--	1.70E-01	--	1.30E-02	Yes	No
7440-50-8	Copper & Compounds	1-hr	4.48E-04	3.56E-03	--	--	2.19E-01	No	No
7440-62-2	Vanadium	24-hr	1.49E-11	--	2.84E-09	--	2.63E-02	No	No
7446-09-05	Sulfur dioxide	1-hr	2.50E-01	1.99E+00	--	--	1.45E+00	Yes	No
74472-37-0	2,3,4,4',5-Pentachlorobiphenyl	year	5.75E-15	--	--	3.94E-10	1.01E-02	No	No
74-83-9	Methyl Bromide	24-hr	8.92E-04	--	1.70E-01	--	6.57E-01	No	No
74-87-3	Methyl Chloride	24-hr	3.82E-03	--	7.28E-01	--	1.18E+01	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
74-90-8	Hydrogen Cyanide	24-hr	7.77E-05	--	1.48E-02	--	1.18E+00	No	No
75-00-3	Ethyl Chloride	24-hr	3.93E-03	--	7.48E-01	--	3.94E+03	No	No
75-01-4	Vinyl Chloride*	Year	2.24E-02	--	--	1.53E+03	2.46E+00	Yes	Yes
75-05-8	Acetonitrile	Year	5.23E-02	--	--	3.58E+03	1.15E+04	No	No
75-07-0	Acetaldehyde	Year	5.61E-02	--	--	3.85E+03	7.10E+01	Yes	No
75-09-2	Dichloromethane	Year	1.53E-01	--	--	1.05E+04	1.92E+02	Yes	No
75-15-0	Carbon disulfide	24-hr	5.47E-03	--	1.04E+00	--	1.05E+02	No	No
75-21-8	Ethylene oxide	Year	1.08E-04	--	--	7.41E+00	2.19E+00	Yes	No
75-25-2	Bromoform	Year	1.29E-04	--	--	8.88E+00	1.74E+02	No	No
75-27-4	Bromodichloromethane	year	3.14E-03	--	--	2.16E+02	5.18E+00	Yes	No
75-34-3	1,1-Dichloroethane	Year	3.73E-04	--	--	2.56E+01	1.20E+02	No	No
75-35-4	1,1-Dichloroethylene	24-hr	4.27E-02	--	8.13E+00	--	2.63E+01	No	No
75-44-5	Phosgene	24-hr	9.84E-06	--	1.87E-03	--	3.94E-02	No	No
75-45-6	Chlorodifluoromethane	24-hr	1.39E-02	--	2.65E+00	--	6.57E+03	No	No
75-68-3	1-Chloro-1,1-difluoroethane	24-hr	1.48E-02	--	2.82E+00	--	6.57E+03	No	No
76-44-8	Heptachlor*	year	4.04E-05	--	--	2.77E+00	1.48E-02	Yes	Yes
7664-38-2	Phosphoric Acid	24-hr	1.39E-15	--	2.64E-13	--	9.20E-01	No	No
7664-41-7	Ammonia	24-hr	1.37E+01	--	2.62E+03	--	9.31E+00	Yes	No
7664-93-9	Sulfuric Acid	24-hr	3.41E-09	--	6.49E-07	--	1.31E-01	No	No
7697-37-2	Nitric Acid	1-hr	5.66E-12	4.49E-11	--	--	1.88E-01	No	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
7723-14-0	Phosphorous	24-hr	4.72E-07	--	8.99E-05	--	2.63E+00	No	No
77-47-4	Hexachlorocyclopentadiene	24-hr	7.38E-05	--	1.41E-02	--	2.60E-02	No	No
7782-49-2	Selenium & Selenium Compounds (other than Hydrogen Selenide)	24-hr	7.78E-05	--	1.48E-02	--	2.63E+00	No	No
78-87-5	1,2-Dichloropropane	Year	6.68E-04	--	--	4.58E+01	1.92E+01	Yes	No
78-93-3	Methyl Ethyl Ketone	24-hr	1.31E-01	--	2.50E+01	--	6.57E+02	No	No
79-00-5	1,1,2-Trichloroethane	Year	8.08E-03	--	--	5.54E+02	1.20E+01	Yes	No
79-01-6	Trichloroethylene*	Year	2.22E-02	--	--	1.52E+03	9.59E+01	Yes	Yes
79-10-7	Acrylic Acid	24-hr	9.83E-03	--	1.87E+00	--	1.31E-01	Yes	No
79-34-5	1,1,2,2-Tetrachloroethane	Year	1.16E-02	--	--	7.96E+02	3.30E+00	Yes	No
79-46-9M	2-Nitropropane	24-hr	2.61E-03	--	4.98E-01	--	2.63E+00	No	No
8001-35-2	Toxaphene	year	2.73E-14	--	--	1.87E-09	5.64E-01	No	No
80-62-6	Methyl methacrylate	24-hr	9.84E-06	--	1.87E-03	--	9.20E+01	No	No
822-06-0	Hexamethylene-1,5-diisocyanate	24-hr	7.38E-05	--	1.41E-02	--	9.20E-03	Yes	No
85-44-9	Phthalic anhydride	24-hr	7.38E-05	--	1.41E-02	--	2.63E+00	No	No
87-68-3	Hexachlorobutadiene	Year	1.59E-02	--	--	1.09E+03	8.73E+00	Yes	No
87-86-5	Pentachlorophenol	year	1.49E-03	--	--	1.02E+02	4.16E+01	Yes	No
88-06-2	2,4,6-Trichlorophenol	year	2.95E-04	--	--	2.03E+01	9.59E+00	Yes	No
90-04-0	o-Anisidine	year	7.38E-05	--	--	5.06E+00	4.80E+00	Yes	No

Table B-1. Toxic Air Pollutant Emission Rates and Comparison to the WAC 173-460-150 SQER Levels

CAS #	Compound	Averaging Period	Emissions				SQER (lb/averaging period)	Above SQER?	Above SQER & Potential Fetoneurotoxin?
			Total (g/s)	Total (lbs/hr	Total (lbs/24-hr)	Total (lbs/yr)			
91-20-3M	Naphthalene	Year	1.88E-04	--	--	1.29E+01	5.64E+00	Yes	No
91-94-1	3,3'-Dichlorobenzidine	year	7.38E-05	--	--	5.06E+00	5.64E-01	Yes	No
924-16-3	n-Nitroso-di-n-butylamine	Year	3.63E-05	--	--	2.49E+00	6.20E-02	Yes	No
930-55-2	n-Nitrosopyrrolidine	Year	2.65E-05	--	--	1.81E+00	3.20E-01	Yes	No
94-59-7	Safrole	year	7.38E-05	--	--	5.06E+00	3.05E+00	Yes	No
95-47-6	o-Xylene	24-hr	2.19E-02	--	4.18E+00	--	2.90E+01	No	No
95-48-7M	2-Methylphenol	24-hr	4.61E-04	--	8.77E-02	--	7.89E+01	No	No
95-53-4	o-Toluidine	year	9.84E-06	--	--	6.74E-01	3.76E+00	No	No
96-12-8	1,2-Dibromo-3-chloropropane	year	7.38E-05	--	--	5.06E+00	1.01E-01	Yes	No
96-18-4	1,2,3-Trichloropropane	24-hr	9.84E-06	--	1.87E-03	--	2.42E-01	No	No
96-45-7	Ethylene thiourea	year	7.38E-05	--	--	5.06E+00	1.48E+01	No	No
98-82-8	Cumene	24-hr	9.64E-04	--	1.84E-01	--	5.26E+01	No	No

*Compound exceeds the SQER and is a potential neurotoxin. As required by WAC 173-460-090, compound is included in the health impact assessment.

APPENDIX C

TOXICOLOGICAL SUMMARY OF NEUROTOXINS EXCEEDING THE SMALL QUANTITY EMISSION RATE

Table C-1. Toxicological Summary of Neurotoxins Exceeding the Small Quantity Emission Rate

CAS#	Chemical Name	Routes of Exposure	Target Organs	Acute Health Effects	Chronic Health Effects
127-18-4	Perchloroethylene	inhalation, skin absorption, ingestion, skin and/or eye contact	Eyes, skin, respiratory system, liver, kidneys, central nervous system	The substance is irritating to the eyes, the skin and the respiratory tract. If this liquid is swallowed, aspiration into the lungs may result in chemical pneumonitis. The substance may cause effects on the central nervous system. Exposure at high levels may result in unconsciousness	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the liver and kidneys. This substance is probably carcinogenic to humans.
1336-36-3	Polychlorinated Biphenyls (PCBs)	inhalation, skin absorption	Liver	Can irritate the skin and eyes. Inhalation can irritate the nose, throat, and lungs. Can cause headache, nausea, vomiting, loss of weight and abdominal pain.	May damage the liver. Probable Carcinogen and Teratogen in humans. Evidence that they cause cancer of the skin, brain, and pancreas in humans and have been shown to cause liver and pituitary cancer and leukemia in animals.
593-74-8	Dimethyl Mercury	inhalation, ingestion, skin absorption	Central Nervous System	The substance is irritating to the eyes, the skin and the respiratory tract. The substance may cause effects on the central nervous system, resulting in impaired functions. Exposure may result in death. The effects may be delayed. Medical observation is indicated.	The substance may have effects on the central nervous system, resulting in impaired functions. This substance is possibly carcinogenic to humans. Causes toxicity to human reproduction or development.

Table C-1. Toxicological Summary of Neurotoxins Exceeding the Small Quantity Emission Rate

CAS#	Chemical Name	Routes of Exposure	Target Organs	Acute Health Effects	Chronic Health Effects
71-43-2	Benzene	inhalation, skin absorption, ingestion, skin and/or eye contact	Eyes, skin, respiratory system, blood, central nervous system, bone marrow	The substance is irritating to the eyes, the skin and the respiratory tract. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system, resulting in lowering of consciousness. Exposure far above the occupational exposure limit value may result in unconsciousness and death.	The liquid defats the skin. The substance may have effects on the bone marrow and immune system, resulting in a decrease of blood cells. This substance is carcinogenic to humans. Studies in animals suggest that inhalation exposure to benzene results in depressed electrical activity in the brain, loss of involuntary reflexes, narcosis, and other symptoms.
7440-38-2	Arsenic & Inorganic Arsenic Compounds	inhalation, skin absorption, skin and/or eye contact, ingestion	Liver, kidneys, skin, lungs, lymphatic system	Ulceration of nasal septum, dermatitis, gastrointestinal disturbances, peripheral neuropathy, respiratory irritation, hyperpigmentation of skin.	Potential occupational carcinogen to the lungs and liver. Evidence from epidemiological studies that inhaled inorganic arsenic can produce neurological effects, peripheral neuropathy sensory and motor polyneuropathy, pseudoneuroasthenic syndrome, toxic encephalopathy, auditory nerve damage, reduced verbal IQ impairment, development effects by inhalation exposure in laboratory animals.
7440-43-9	Cadmium & Compounds	inhalation, ingestion	respiratory system, kidneys, prostate, blood	Pulmonary edema, dyspnea, cough, chest tightness, substernal pain; headache; chills, muscle aches; nausea, vomiting, diarrhea; anosmia, emphysema, proteinuria, mild anemia.	Potential occupational carcinogen to the prostate and lugs. Neurodevelopmental effects including alterations in motor activity and delays in the development of sensory motor coordination reflexes.

Table C-1. Toxicological Summary of Neurotoxins Exceeding the Small Quantity Emission Rate

CAS#	Chemical Name	Routes of Exposure	Target Organs	Acute Health Effects	Chronic Health Effects
75-01-4	Vinyl Chloride	inhalation, skin and/or eye contact (liquid)	Liver, central nervous system, blood, respiratory system, lymphatic system	The substance is irritating to the eyes. The liquid may cause frostbite. The substance may cause effects on the central nervous system. Exposure could cause lowering of consciousness. Medical observation is indicated.	The substance may have effects on the liver, spleen, blood and peripheral blood vessels, and tissue and bones of the fingers. This substance is carcinogenic to humans.
76-44-8	Heptachlor	Inhalation, ingestion	Nervous system, liver, kidney	Convulsions, tremors, headache, dizziness, respiratory depression, coma.	Cancer, endocrine disruption, developmental toxicity
79-01-6	Trichloroethylene	inhalation, skin absorption, ingestion, skin and/or eye contact	Eyes, skin, respiratory system, heart, liver, kidneys, central nervous system	The substance is irritating to the eyes and the skin. Swallowing the liquid may cause aspiration into the lungs with the risk of chemical pneumonitis. The substance may cause effects on the central nervous system, resulting in respiratory failure. Exposure could cause lowering of consciousness	Repeated or prolonged contact with skin may cause dermatitis. The substance may have effects on the central nervous system, resulting in loss of memory. The substance may have effects on the liver and kidneys (see Notes). This substance is probably carcinogenic to humans.

Data obtained from the Centers for Disease Control web site (http://www.cdc.gov/niosh/) and Agency for Toxic Substances & Disease Registry http://www.atsdr.cdc.gov/toxprofiles/index.asp.

APPENDIX D

DIMETHYL MERCURY HEALTH IMPACT ASSESSMENT DOSE SPREADSHEET

Spreadsheet Owner & Developer:	T. Williams
Spreadsheet Verification Form:	Dimethyl Mercury Health Impact Assessment Dose Calculation for RPP-ENV-59016
Date:	10/20/2015

Objective/Purpose Of The Spreadsheet:

The purpose of this calculation was to estimate the 30-year and 70-year dose to the public from emissions of dimethyl mercury and other neurotoxic compounds on the Hanford Site in support of RPP-ENV-59016, Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions.

The Worksheets In The Spreadsheet Are As Follows:

Documentation: Documents the contents of the spreadsheet in accordance with TFC-ENG-DESIGN-C-32, “Spreadsheet Development and Verification."

Change Log: Documents the revision history, change history, and verification history of the spreadsheet per TFC-ENG-DESIGN-C-32.

Summary: This worksheet totals the inhalation and plant ingestion hazard quotients to calculate a total hazard index for each exposure scenario, following California EPA, February 2015 guidelines.

Dimethyl Mercury, Arsenic & Inorganic Compounds, Benzene, Heptachlor, Hexachlorobenzene, Elemental Mercury, Perchloroethylene, Trichloroethylene: These worksheets calculate 1) the total inhalation dose from air modeling results, 2) the ingestion from plant consumption using the concentration of the compound in the soil based upon deposition data and the plant concentration from deposition and root absorption, and 3) the hazard quotients for the 30-year and 70-year exposure scenarios. All calculations and assumptions (unless otherwise noted) follow California EPA, February 2015, guidelines.

Describe Any Macros Or Add In Software:

No macros or add in software was used.

Assumptions:

Assumed two exposure scenarios: a 30-year and a 70-year, as explained in RPP-ENV-59016.

For the 30-year and 70-year scenario, assumed the maximum modeled 24-hour air concentration & deposition rate for each compound, as detailed in RPP-ENV-59016.

Assumed all sources were running and mixing during the entire year.

Individual compound assumptions are noted within each spreadsheet.

References:

California Environmental Protection Agency, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments.* Office of Environmental Health Hazard Assessment, Oakland, California.

National Research Council, 2000. *Toxicological Effects of Methylmercury.* The National Academies, Washington, D.C.

RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0. Washington River Protection Solutions, Richland, Washington.

TFC-ENG-DESIGN-C-32, Rev. H, “Utility Calculation Software Management,” Washington River Protection Solutions, Richland, Washington.

Wesely, et al. June 2002. *Deposition parameterizations for the Industrial Source Complex (ISC3) Model*. ANL/ER/TR-01/003. Environmental Research Division, Argonne National Laboratory, Argonne, IL.

U.S. Environmental Protection Services, Soil Screening Guidance. www.epa.gov/superfund/health/conmedia/soil/pdfs/part_5.pdf

Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values (May 13, 2015). Available at: http://www.arb.ca.gov/toxics/healthval/healthval.htm (AB 2588 Air Toxics “Hot Spots” REL).

OEHHA Air Toxicology and Epidemiology. "All OEHHA Acute, 8-hour, and Chornic Reference Exposure Levels (chRELs) as of June 2014." Available at: http://oehha.ca.gov/air/allrels.html.

USEPA Integrated Risk Information System (IRIS): Available at https://www2.epa.gov/iris.

Health Impact Assessment Hazard Index Calculation

This spreadsheet calculates the total hazard index for the 30-year and 70-year exposure scenarios. All hazard quotient values in this spreadsheet are referenced from each compound's dose calculation spreadsheet.

	Hazard Quotient	
	30-Year	70-Year
Dimethyl Mercury	3.6E-01	6.7E-01
Arsenic & Inorganic Compounds	9.4E-05	1.1E-04
Benzene	2.4E-03	2.4E-03
Heptachlor	1.9E-06	1.9E-06
Hexchlorobenzene	3.2E-06	5.4E-06
Mercury, Elemental	2.2E-03	3.1E-03
Perchloroethylene	1.9E-04	1.9E-04
Trichloroethylene	5.3E-05	5.3E-05
Hazard Index	3.7E-01	6.7E-01

Dimethyl Mercury Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

DMM Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R4]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	($\mu g/m^3$)	($\mu g/m^3$)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	5.4E-03	1.4E-01	3.9E-02	3.2E-05	1.0E-04	3.2E-01	3.6E-01
70-Year	5.4E-03	1.4E-01	3.9E-02	6.3E-05	1.0E-04	6.3E-01	6.7E-01

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) ($\mu g/m^3$) / Chronic Inhalation REL/RfC ($\mu g/m^3$)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3:

R4: US EPA. IRIS on Methylmercury (MeHg) CASRM 22967-92-6. Available at https://www2.epa.gov/iris. Accessed on October 20, 2015.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	5.4E-03	5.4E-03
70-Year	5.4E-03	5.4E-03

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)												
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)									
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m^2 per day)	($\mu g/m^2$ per day)	(days)		(day)	(day)	(days)		(m)	(kg/m^3)	($\mu g/kg$ soil)
30-Year	9.0E-07	9.0E-01	1.0E+08	6.9E-09	0	10,950	10,950	0.42	0.15	1,333	2.5E+01
70-Year	9.0E-07	9.0E-01	1.0E+08	6.9E-09	0	25,550	25,550	2.26	0.15	1,333	5.8E+01

Assumptions:

A: Assumed chemical specific half-life of inorganic mercury due to lack of data for dimethyl mercury. Based on calculation, this caused some chemical loss in the 30-year scenario, but returned a highly conservative soil concentration in the 70-year scenario.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate ($\mu g/m^2$ day) = Model Deposition Rate (g/m^2 day) * 1,000,000 ($\mu g/g$)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. ($\mu g/kg$ soil)= (Deposition Rate($\mu g/m^2$ day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m^3)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: $C_s = Dep \times X / (K_s \times SD \times BD \times T_t)$

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m^2-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m^3)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)											
		Root Uptake - Organic (Eq. 5.3.4.1 D)			Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	Uptake Factor[R2, A] (Table 5-2a, pg 5-19)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E=C*D	F	G	H	I	J=((B*F)/(G*H)) * (1-exp(-G*I))[R4]	K= E+J[R3]
	(µg/m² per day)	(µg/kg)		(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	9.0E-01	2.5E+01	9.0E-02	2.2E+00	0.2	0.1	2	45	8.9E-01	3.1E+00
70-Year	9.0E-01	5.8E+01	9.0E-02	5.2E+00	0.2	0.1	2	45	8.9E-01	6.1E+00

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathering Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J	C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)
E	C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B	Dep = Deposition on affected vegetation per day (ug/m²/d)
F	IF = Interception fraction
G	k = Weathering constant (d-1)
H	Y = Yield (kg/m2)
	e = Base of natural logarithm (2.718)
I	T = Growth period (d)

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R3] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R3] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	3.1E+00	10.8	1	1	350	30	1.0E-06	10,950	3.2E-05
70-years	6.1E+00	10.8	1	1	350	70	1.0E-06	25,550	6.3E-05

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Arsenic & Other Compounds Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Arsenic Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	($\mu g/m^3$)	($\mu g/m^3$)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	6.6E-07	1.5E-02	4.4E-05	1.5E-08	3.0E-04	5.0E-05	9.4E-05
70-Year	6.6E-07	1.5E-02	4.4E-05	1.9E-08	3.0E-04	6.4E-05	1.1E-04

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) ($\mu g/m^3$) / Chronic Inhalation REL/RfC ($\mu g/m^3$)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: Inhalation REL = OEHHA. RfD = US EPA IRIS.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	6.6E-07	6.6E-07
70-Year	6.6E-07	6.6E-07

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
		Integral Function[R2] (Equation 5.3.2 C pg 5-8)									
Exposure Scenario[R1]	Deposition Rate[R2] (Equation 5.3.2 B pg 5-7)	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B]	(pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B=AIR*.02 m/s*86,400	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J		K	L=(B*I)/(E*J*K*H)[R3]
	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)		(kg/m³)	(µg/kg soil)
30-Year	1.1E-03	1.0E+08	6.9E-09	0	10,950	10,950	0.42	0.15		1,333	3.1E-02
70-Year	1.1E-03	1.0E+08	6.9E-09	0	25,550	25,550	2.26	0.15		1,333	7.3E-02

Assumptions:

A: Assumed given chemical specific half-life of Arsenic & Inorganic Compounds.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: C_s = Dep x X / (K_s x SD x BD x T_t)

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)										
		Root Uptake - Inorganic (Eq. 5.3.4.1 C)			Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	Uptake Factor[R2, A] (Table 5-2a, pg 5-19)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E=C*D	F	G	H	I	J=((B*F)/(G*H)) * (1-exp(-G*I))[R4]	K= E+J[R3]
	(µg/m² per day)	(µg/kg)		(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	1.1E-03	3.1E-02	1.0E-02	3.1E-04	0.2	0.1	2	45	1.1E-03	1.4E-03
70-Year	1.1E-03	7.3E-02	1.0E-02	7.3E-04	0.2	0.1	2	45	1.1E-03	1.9E-03

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathering Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

E C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

F IF = Interception fraction

G k = Weathering constant (d-1)

H Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

I T = Growth period (d)

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R3] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R3] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	1.4E-03	10.8	1	1	350	30	1.0E-06	10,950	1.5E-08
70-years	1.9E-03	10.8	1	1	350	70	1.0E-06	25,550	1.9E-08

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Benzene Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Benzene Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	7.1E-03	3.0E+00	2.4E-03	9.5E-09	4.0E-03	2.4E-06	2.4E-03
70-Year	7.1E-03	3.0E+00	2.4E-03	9.5E-09	4.0E-03	2.4E-06	2.4E-03

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: RfC and RfD = US EPA IRIS.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	7.1E-03	7.1E-03
70-Year	7.1E-03	7.1E-03

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)								
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	9.2E-10	9.2E-04	1.7E+01	4.1E-02	0	10,950	10,950	10925.47	0.15	1,333	1.1E-04
70-Year	9.2E-10	9.2E-04	1.7E+01	4.1E-02	0	25,550	25,550	25525.47	0.15	1,333	1.1E-04

Assumptions:

A: Agency for Toxic Substances & Disesase Registry: Toxicological Profile for Benzene, available at: http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=40&tid=14

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: C_s = Dep x X / (K_s x SD x BD x T_t)

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

		Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)										
		Root Uptake - Organic (Eq. 5.3.4.1 C and 5.3.4.1 D)					Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	K_{ow}	K_{oc}	Root Uptake Algorithm[R5, R6] (Eq. 5.3.4.1 D, pg 5-11)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2, A] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2, R4] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E	F= [(0.03*D^0.77) + 0.82] / [(E)(0.1)]	G=C*F	H	I	J	K	L=((B*H)/(I*J)) * (1-exp(-I*K))[R4]	M= G+L[R3]
	(µg/m² per day)	(µg/kg)				(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	9.2E-04	1.1E-04	1.3E+02	5.9E+01	3.6E-01	4.0E-05	0.2	0.1	2	45	9.1E-04	9.5E-04
70-Year	9.2E-04	1.1E-04	1.3E+02	5.9E+01	3.6E-01	4.0E-05	0.2	0.1	2	45	9.1E-04	9.5E-04

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathing Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

G C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

H IF = Interception fraction

I k = Weathering constant (d-1)

J Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

K T = Growth period (d)

R5: $UF = [(0.03*K_{ow}^{\wedge 0.77}) + 0.82] / [(K_{oc})(F_{oc})]$

R6: USEPA, Publication 175223, Appendix K Soil Organic Carbon (K_{oc}) / Water (K_{ow}) Partition Coefficients

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R4] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2, R3] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R4] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	9.5E-04	10.8	0.97	1	350	30	1.0E-06	10,950	9.5E-09
70-years	9.5E-04	10.8	0.97	1	350	70	1.0E-06	25,550	9.5E-09

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: The Risk Assessment Information System Toxicity Profile on Benzene. Available at: http://rais.ornl.gov/tox/profiles/benzene.html.

R4: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Heptachlor Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Heptachlor Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	1.7E-05	5.0E+02	3.4E-08	9.1E-10	5.0E-04	1.8E-06	1.9E-06
70-Year	1.7E-05	5.0E+02	3.4E-08	9.2E-10	5.0E-04	1.8E-06	1.9E-06

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: Inhalation = OSHA PEL, Oral RfD = USEPA IRIS

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	($\mu g/m^3$)	($\mu g/m^3$)
30-Year	1.7E-05	1.7E-05
70-Year	1.7E-05	1.7E-05

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)												
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)									
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	1.1E-10	1.1E-04	1.3E+03	5.4E-04	0	10,950	10,950	9112.13	0.15	1,333	8.6E-04
70-Year	1.1E-10	1.1E-04	1.3E+03	5.4E-04	0	25,550	25,550	23707.29	0.15	1,333	9.6E-04

Assumptions:

A: Pesticide Management Education Program at Cornell University Cooperative Extension lists Heptachlor soil half-life at 6 months - 3.5 years. Assumed conservative 3.5 years. Available at: pmep.cce.cornell.edu.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: $C_s = Dep \times X / (K_s \times SD \times BD \times T_t)$

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

		Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)										
		Root Uptake - Organic (Eq. 5.3.4.1 C and 5.3.4.1 D)					Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	K_{ow}	K_{oc}	Root Uptake Algorithm[R5, R6] (Eq. 5.3.4.1 D, pg 5-11)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2, R4] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E	F= [(0.03*D^0.77) + 0.82] / [(E)(0.1)]	G=C*F	H	I	J	K	L=((B*H)/(I*J)) * (1-exp(-I*K))[R4]	M= G+L[R3]
	(µg/m² per day)	(µg/kg)				(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	1.1E-04	8.6E-04	1.8E+06	1.4E+06	1.4E-02	1.2E-05	0.2	0.1	2	45	1.1E-04	1.2E-04
70-Year	1.1E-04	9.6E-04	1.8E+06	1.4E+06	1.4E-02	1.3E-05	0.2	0.1	2	45	1.1E-04	1.2E-04

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathing Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

G C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

H IF = Interception fraction

I k = Weathering constant (d-1)

J Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

K T = Growth period (d)

R5: UF = $[(0.03*K_{ow}{}^{\wedge 0.77}) + 0.82] / [(K_{oc})(F_{oc})]$

R6: USEPA, Publication 175223, Appendix K Soil Organic Carbon (K_{oc}) / Water (K_{ow}) Partition Coefficients

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R4] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2, R3] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R4] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	1.2E-04	10.8	0.72	1	350	30	1.0E-06	10,950	9.1E-10
70-years	1.2E-04	10.8	0.72	1	350	70	1.0E-06	25,550	9.2E-10

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: The Risk Assessment Information System Toxicity Profile on Heptachlor. Available at: http://rais.ornl.gov/tox/profiles/heptachlor.html.

R4: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Hexachlorobenzene Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Hexachlorobenzene Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	3.8E-06	3.0E+00	1.3E-06	1.6E-09	8.0E-04	2.0E-06	3.2E-06
70-Year	3.8E-06	3.0E+00	1.3E-06	3.3E-09	8.0E-04	4.1E-06	5.4E-06

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: Inhalation REL = California EPA, RfD = US EPA IRIS.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	3.8E-06	3.8E-06
70-Year	3.8E-06	3.8E-06

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)								
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	2.5E-11	2.5E-05	1.0E+08	6.9E-09	0	10,950	10,950	0.42	0.15	1,333	6.8E-04
70-Year	2.5E-11	2.5E-05	1.0E+08	6.9E-09	0	25,550	25,550	2.26	0.15	1,333	1.6E-03

Assumptions:

A: Assumed given chemical specific half-life of Hexachlorobenzene.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: C_s = Dep x X / (K_s x SD x BD x T_t)

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m^2-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m^3)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

		Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)											
		Root Uptake - Organic (Eq. 5.3.4.1 C and 5.3.4.1 D)					Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	K_{ow}	K_{oc}	Root Uptake Algorithm[R5, R6] (Eq. 5.3.4.1 D, pg 5-11)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2, R4] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E	F= [(0.03*D^0.77) + 0.82] / [(E)(0.1)]	G=C*F	H	I	J	K	L=((B*H)/(I*J)) * (1-exp(-I*K))[R4]	M= G+L[R3]
	(µg/m² per day)	(µg/kg)				(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	2.5E-05	6.8E-04	7.8E+05	5.5E+04	1.9E-01	1.3E-04	0.2	0.1	2	45	2.4E-05	1.5E-04
70-Year	2.5E-05	1.6E-03	7.8E+05	5.5E+04	1.9E-01	3.0E-04	0.2	0.1	2	45	2.4E-05	3.2E-04

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathing Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 J B)

G C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

H IF = Interception fraction

I k = Weathering constant (d-1)

J Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

K T = Growth period (d)

R5: $UF = [(0.03*K_{ow}^{0.77}) + 0.82] / [(K_{oc})(F_{oc})]$

R6: USEPA, Publication 175223, Appendix K Soil Organic Carbon (K_{oc}) / Water (K_{ow}) Partition Coefficients

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R3] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R3] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	1.5E-04	10.8	1	1	350	30	1.0E-06	10,950	1.6E-09
70-years	3.2E-04	10.8	1	1	350	70	1.0E-06	25,550	3.3E-09

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Mercury, Elemental Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Elemental Mercury Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	8.6E-05	3.0E-01	2.9E-04	3.1E-07	1.6E-04	1.9E-03	2.2E-03
70-Year	8.6E-05	3.0E-01	2.9E-04	4.5E-07	1.6E-04	2.8E-03	3.1E-03

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: RfC = US EPA IRIS, Oral REL = OEHHA.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	8.6E-05	8.6E-05
70-Year	8.6E-05	8.6E-05

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)								
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	1.9E-08	1.9E-02	1.0E+08	6.9E-09	0	10,950	10,950	0.42	0.15	1,333	5.3E-01
70-Year	1.9E-08	1.9E-02	1.0E+08	6.9E-09	0	25,550	25,550	2.26	0.15	1,333	1.2E+00

Assumptions:

A: Assumed given chemical specific half-life of inorganic mercury.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: $C_s = Dep \times X / (K_s \times SD \times BD \times T_t)$

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)										
		Root Uptake - Inorganic (Eq. 5.3.4.1 C)			Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	Uptake Factor[R2, A] (Table 5-2a, pg 5-19)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E=C*D	F	G	H	I	J=((B*F)/(G*H)) * (1-exp(-G*I))[R4]	K= E+J[R3]
	(µg/m² per day)	(µg/kg)		(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	1.9E-02	5.3E-01	2.0E-02	1.1E-02	0.2	0.1	2	45	1.9E-02	3.0E-02
70-Year	1.9E-02	1.2E+00	2.0E-02	2.5E-02	0.2	0.1	2	45	1.9E-02	4.4E-02

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathering Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

E C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

F IF = Interception fraction

G k = Weathering constant (d-1)

H Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

I T = Growth period (d)

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R3] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R3] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	3.0E-02	10.8	1	1	350	30	1.0E-06	10,950	3.1E-07
70-years	4.4E-02	10.8	1	1	350	70	1.0E-06	25,550	4.5E-07

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Perchloroethylene Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Perchloroethylene Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	7.1E-03	4.0E+01	1.8E-04	5.6E-08	6.0E-03	9.3E-06	1.9E-04
70-Year	7.1E-03	4.0E+01	1.8E-04	5.6E-08	6.0E-03	9.3E-06	1.9E-04

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: US EPA. IRIS on Methyl Mercury.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	7.1E-03	7.1E-03
70-Year	7.1E-03	7.1E-03

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)								
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	3.6E-09	3.6E-03	2.7E+02	2.6E-03	0	10,950	10,950	10560.39	0.15	1,333	6.7E-03
70-Year	3.6E-09	3.6E-03	2.7E+02	2.6E-03	0	25,550	25,550	25160.39	0.15	1,333	6.8E-03

Assumptions:

A: USEPA Technical Factsheet on Tetrachloroethylene. Available at: http://water.epa.gov/drink/contaminants/basicinformation/historical/upload/Archived-Technical-Fact-Sheet-on-Tetrachloroethylene.pdf

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: C_s = Dep x X / (K_s x SD x BD x T_t)

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

		Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)											
		Root Uptake - Organic (Eq. 5.3.4.1 C and 5.3.4.1 D)					Vegetation Deposition[R4] (Eq 5.3.4.1 B)						
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	K_{ow}	K_{oc}	Root Uptake Algorithm[R5, R6] (Eq. 5.3.4.1 D, pg 5-11)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2, R4] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E	F= [(0.03*D^0.77) + 0.82] / [(E)(0.1)]	G=C*F	H	I	J	K	L=((B*H)/(I*J)) * (1-exp(-I*K))[R4]	M= G+L[R3]
	($\mu g/m^2$ per day)	($\mu g/kg$)				($\mu g/kg$)			(kg/m^2)	(days)	($\mu g/kg$)	($\mu g/kg$)
30-Year	3.6E-03	6.7E-03	4.7E+02	1.6E+02	2.7E-01	1.8E-03	0.2	0.1	2	45	3.5E-03	5.4E-03
70-Year	3.6E-03	6.8E-03	4.7E+02	1.6E+02	2.7E-01	1.9E-03	0.2	0.1	2	45	3.5E-03	5.4E-03

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathing Constant*Growth Period))

Total Veg. Conc. ($\mu g/kg$)= Root Uptake Concentration ($\mu g/kg$)+ Vegetation Concentration($\mu g/kg$) - Deposition ($\mu g/kg$)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J — C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

G — C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B — Dep = Deposition on affected vegetation per day ($ug/m^2/d$)

H — IF = Interception fraction

I — k = Weathering constant (d-1)

J — Y = Yield ($kg/m2$)

e = Base of natural logarithm (2.718)

K — T = Growth period (d)

R5: $UF = [(0.03*K_{ow}^{0.77}) + 0.82] / [(K_{oc})(F_{oc})]$

R6: USEPA, Publication 175223, Appendix K Soil Organic Carbon (K_{oc}) / Water (K_{ow}) Partition Coefficients

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R4] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2, R3] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R4] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	5.4E-03	10.8	1	1	350	30	1.0E-06	10,950	5.6E-08
70-years	5.4E-03	10.8	1	1	350	70	1.0E-06	25,550	5.6E-08

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: The Risk Assessment Information System Toxicity Profile on Perchloroethylene states "substantial" absorption. Used conservative values of 1. Available at: http://rais.ornl.gov/tox/profiles/perchloroethylene.html.

R4: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs

Trichloroethylene Total Dose and Hazard Quotient Calculation

Calculation 1: determines the hazard quotients using inputs from Calculations 2 and 5

Trichloroethylene Total Dose[R2]

Exposure Scenario[R1]	Dose - Inhalation	Chronic Inhalation REL/RfC[R3]	Dose - Inhalation Hazard Quotient	Dose - Plant Ingestion	Chronic Oral REL/RfD[R3]	Dose - Plant Ingestion Hazard Quotient	Total Dose Hazard Quotient
A	B (Calculation 2)	C	D=B/C	E (Calculation 5)	F	G=E/F	H=D+G
	(µg/m³)	(µg/m³)	(unitless)	(mg/kg BW per day)	(mg/kg BW per day)	(unitless)	(unitless)
30-Year	7.1E-03	6.0E+02	1.2E-05	2.0E-08	5.0E-04	4.1E-05	5.3E-05
70-Year	7.1E-03	6.0E+02	1.2E-05	2.1E-08	5.0E-04	4.1E-05	5.3E-05

Calculations:

Inhalation Hazard Quotient (unitless) = Inhalation (modeled air concentration) (µg/m³) / Chronic Inhalation REL/RfC (µg/m³)

Plant Ingestion Hazard Quotient (unitless) = Plant Ingestion (mg/kg BW per day) / Chronic Oral REL/RfD (mg/kg BW per day)

Total Dose Hazard Quotient (unitless)= Inhalation + Plant Ingestion Hazard Quotient

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: Inhalation REL = OEHHA, RfD = US EPA IRIS.

Calculation 2: determine the dose from inhalation exposure

Dose - Inhalation [R2] (Equation 5.4.1.4 A- pg 5-33)[A]		
Exposure Scenario[R1]	Modeled Air Concentration[R1, B]	Dose - Inhalation
A	B	C=B
	(µg/m³)	(µg/m³)
30-Year	7.1E-03	7.1E-03
70-Year	7.1E-03	7.1E-03

Assumptions:

A: Noncancer health risk equation.

B: Highest modeled concentration over 5 years.

Calculations:

Modeled Air Concentration = Dose - Inhalation

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

Calculation 3: determine the soil concentration based on modeled deposition rate

Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)											
			Integral Function[R2] (Equation 5.3.2 C pg 5-8)								
Exposure Scenario[R1]	Model Deposition Rate[R1]	Model Deposition Rate[R1]	Chemical Specific Half Life[R2, A] (Table 5-2 pg 5-18)	Soil Elimination Constant[R2] (Equation 5.3.2 D pg 5-8)	Beginning of Evaluation Period[R2]	End of Evaluation Period[R2]	Total Days of Exposure[R1]	Integral Function[R2] (Equation 5.3.2 C pg 5-8)	Soil Mixing Depth[R2, B] (pg 5-7)	Soil Bulk Density[R2, B] (pg 5-7)	Soil Concentration[R2] (Equation 5.3.2 A pg 5-6)
A	B	C=B*1,000,000	D	E= 0.693/D	F	G	H= G-F	I=[{EXP-(E*G)-EXP-(E*F)}/E]+H	J	K	L=(C*I)/(E*J*K*H)[R3]
	(g/m² per day)	(µg/m² per day)	(days)		(day)	(day)	(days)		(m)	(kg/m³)	(µg/kg soil)
30-Year	1.2E-09	1.2E-03	3.7E+02	1.9E-03	0	10,950	10,950	10423.30	0.15	1,333	3.0E-03
70-Year	1.2E-09	1.2E-03	3.7E+02	1.9E-03	0	25,550	25,550	25023.30	0.15	1,333	3.0E-03

Assumptions:

A: Estimated at 6 -12 months. Assumed conservative 12 months. EPA/600/R-00/099, March 2001. *Sources, emissions, and exposure for trichloroethylene (TCE) and related chemicals*. Natioanl Center for Environmental Assessment - Washington Office. Office of Research and Development, U.S. Enivronmental Protection Agency.

B: Recommended California EPA 2015 value from page 5-7.

Calculations:

Deposition Rate (µg/m² day) = Model Deposition Rate (g/m² day) * 1,000,000 (µg/g)

Soil Elimination Constant = 0.693/Chemical Elimination Constant

Total Days of Exposure = End of Evaluation Period - Beginning of Evaluation Period

Integral Function =[{exp-(Soil Elim. Const.(1/day) * End Eval Period(day))-exp-(Soil Elim Cont.(1/day) * Beg. Eval Period(day))}/ Soil Elim Const.(1/day)] + Total Days of Exposure (days)

Soil Conc. (µg/kg soil)= (Deposition Rate(µg/m² day)* Integral Function)/(Soil Elimination Constant(1/days)*Soil Mixing Depth(m)*Soil Bulk Density(kg/m³)*Total Days of Exposure(days))

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments, Office of Environmental Health Hazard Assessment*, Oakland, California.

R3: C_s = Dep x X / (K_s x SD x BD x T_t)

L	C_s= Average soil concentration over the evaluation period (ug/kg)
C	Dep = Deposition on the affected soil area per day (ug/m²-d)
I	X= Integral function for soil accumulation (d)
E	K_s= Soil elimination constant (d^{-1})
J	SD= Soil mixing depth (m)
K	BD= Soil bulk density (kg/m³)
H	T_t= Soil exposure duration or soil accumulation period (d)

Calculation 4: determine the vegetation concentration using soil concentration from Calculation 3 and modeled deposition rate

		Total Vegetation Concentration[R3] (Equation 5.3.4.1 A pg 5-9)											
		Root Uptake - Organic (Eq. 5.3.4.1 C and 5.3.4.1 D)					Vegetation Deposition[R4] (Eq 5.3.4.1 B)					
Exposure Scenario[R1]	Deposition Rate[R1]	Soil Concentration (Soil Conc. Sheet)	K_{ow}	K_{oc}	Root Uptake Algorithm[R5, R6] (Eq. 5.3.4.1 D, pg 5-11)	Root Uptake Concentration[R2] (Eq. 5.3.4.1 C, pg 5-11)	Interception Fraction[R2, A] (pg 5-10)	Weathering Constant[R2] (pg 5-10)	Plant Yield[R2] (pg 5-10)	Growth Period[R2, A] (pg 5-10)	Vegetation Conc. - Deposition[R2, R4] (Eq 5.3.4.1 B pg 5-10)	Total Vegetation Conc. (Equation 5.3.4.1 A pg 5-9)
A	B	C	D	E	F= [(0.03*D^0.77) + 0.82] / [(E)(0.1)]	G=C*F	H	I	J	K	L=((B*H)/(I*J)) * (1-exp(-I*K))[R4]	M= G+L[R3]
	(µg/m² per day)	(µg/kg)				(µg/kg)			(kg/m²)	(days)	(µg/kg)	(µg/kg)
30-Year	1.2E-03	3.0E-03	5.1E+02	1.7E+02	2.7E-01	8.0E-04	0.2	0.1	2	45	1.2E-03	2.0E-03
70-Year	1.2E-03	3.0E-03	5.1E+02	1.7E+02	2.7E-01	8.2E-04	0.2	0.1	2	45	1.2E-03	2.0E-03

Assumptions:

A: Assumed leafy vegetation as most conservative exposure scenario.

Calculations:

Root Uptake = Soil Concentration * Root Uptake Factor

Veg. Conc. - Dep = ((Deposition Rate*Interception Fraction)/(Weathering Constant*Plant Yield))*(1-EXP(-Weathing Constant*Growth Period))

Total Veg. Conc. (µg/kg)= Root Uptake Concentration (µg/kg)+ Vegetation Concentration(µg/kg) - Deposition (µg/kg)

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: $C_v = C_{depv} + C_{trans}$

J C_{depv} = Concentration due to direct depostion (ug/kg) (Eq. 5.3.4.1 B)

G C_{trans} = Concentration in vegetation due to root translocation or uptake (ug/kg) - see Eq 5.3.4.1 C

R4: $C_{depv} = [Dep \times IF / (k \times Y)] \times (1 - e^{-kT})$

B Dep = Deposition on affected vegetation per day (ug/m²/d)

H IF = Interception fraction

I k = Weathering constant (d-1)

J Y = Yield (kg/m2)

e = Base of natural logarithm (2.718)

K T = Growth period (d)

R5: UF = $[(0.03*K_{ow}^{0.77}) + 0.82] / [(K_{oc})(F_{oc})]$

R6: USEPA, Publication 175223, Appendix K Soil Organic Carbon (K_{oc}) / Water (K_{ow}) Partition Coefficients

Calculation 5: determine dose from plant ingestion using vegetation concentration from Calculation 4

Dose - Plant Ingestion[R4] (Eq. 5.4.3.2.3 pg 5-48)									
Exposure Scenario[R1]	Vegetation Concentration (from Veg Conc. Sheet)	Food Consumption Rate[R2, A] (Table 5-15 pg 5-49)	Gastrointestinal Absorption Factor[R2, R3] (Table 5.2b pg 5-19)	Fraction Homegrown[R1, B]	Exposure Frequency[R1]	Exposure Duration[R1]	Conversion Factor[R2]	Averaging Time[R2]	Dose - Plant Ingestion[R4] (Equation 5.4.3.2.3)
(years)	(µg/kg)	(g/kg BW per day)			(days/year)	(years)	(µg/kg to mg/g)	(days)	(mg/kg BW per day)
A	B	C	D	E	F	G	H	I=G*365	J=(B*C*D*E*F*G*H)/I
30-years	2.0E-03	10.8	1	1	350	30	1.0E-06	10,950	2.0E-08
70-years	2.0E-03	10.8	1	1	350	70	1.0E-06	25,550	2.1E-08

Assumptions:

A: Assumed high end per capita food consumption rate for leafy produce as the most conservative scenario.

B: Assumed all food is homegrown as most conservative dose estimate.

Calculations:

Dose-Plant Ingestion = Plant Conc.*Food Consumpt. Rate*Gastrointestinal Factor*Fraction Homegrown*Exposure Frequency*Exposure Duration* Conversion Factor)/Averaging Time

References:

R1: RPP-ENV-59016, 2015. *Second Tier Review Petition for Hanford Tank Farm and Waste Treatment Plant Dimethyl Mercury Emissions*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

R2: California EPA, February 2015. *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, Oakland, California.

R3: The Risk Assessment Information System Toxicity Profile on Trichloroethylene estimates full absorption. Used conservative values of 1. Available at: http://rais.ornl.gov/tox/profiles/trichloroethylene.html.

R4: $DOSE_{food} = C_{food} \times I_{food} \times GRAF \times L \times 10\text{-}6 \times ED/AT$

	$DOSE_{food}$ = Exposure dose through ingestion of home-grown produce or home-raised animal product (mg/kg/d)
B	C_{food} = Concentration (ug/kg) in produce (e.g., exposed, leafy, protected, root) or animal product (e.g., beef, pork, poultry, dairy, eggs)
C	I_{food} = Consumption of produce or animal product (g/kg BW-day)
D	GRAF = Gastrointestinal relative absorption factor (unitless)
E	L = Fraction of produce or animal product consumed that is home-grown (unitless)
F/G	ED = Exposure duration for a specified age group (2 yrs for 0<2, 14 yrs for 2<16, 54 yrs for 16-70
I	AT = Averaging time for lifetime exposure: 70 yrs